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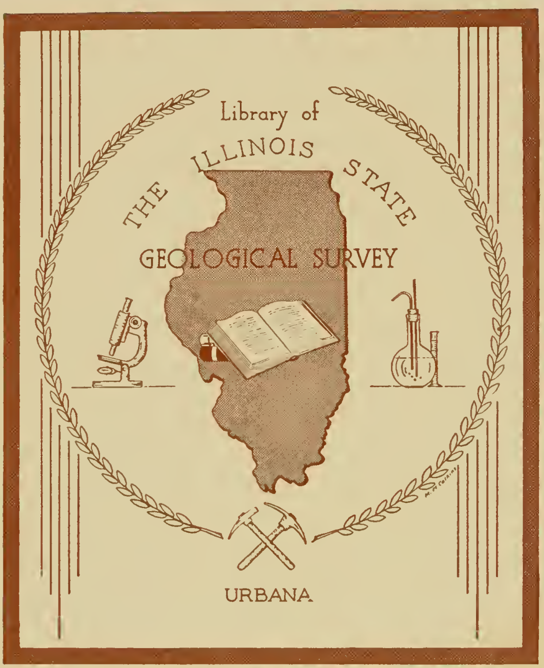

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

BULLETIN NO. 58

THE FLUORSPAR DEPOSITS OF HARDIN AND POPE COUNTIES, ILLINOIS

BY

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PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
1931

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
M. F. Walsh, *Director*

STATE GEOLOGICAL SURVEY DIVISION
M. M. Leighton, *Chief*

Jeffersons Printing & Stationery Co.
Springfield, Illinois

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THE FLUORSPAR DEPOSITS OF HARDIN AND POPE COUNTIES, ILLINOIS

By Edson S. Bastin

CHAPTER I

Introduction

LOCATION OF DISTRICT

One of the most important, if not the most important, fluorspar-producing areas in the world comprises the southeastern part of Illinois and the western part of Kentucky and is designated as the Kentucky-Illinois district (Fig. 1). The Illinois portion of the district lies in Hardin and eastern Pope counties, and all the important deposits in the State are near the towns of Rosiclare and Cave in Rock on Ohio River (Fig. 1 and Pl. I). In Kentucky

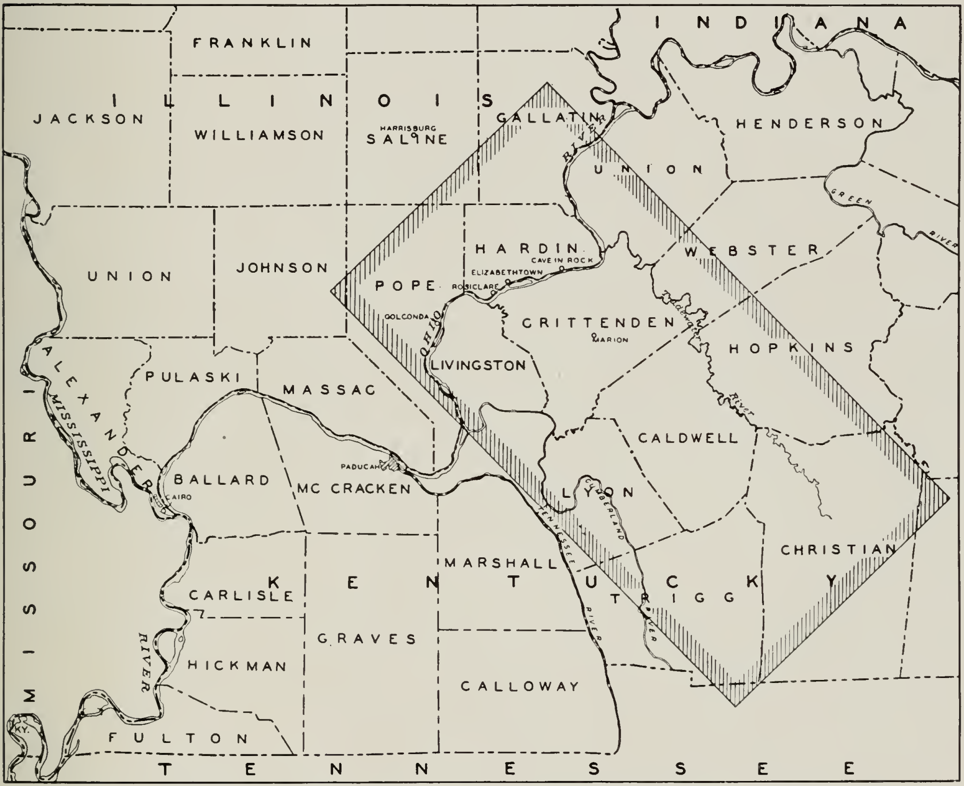

Fig. 1. Index map showing the location of the Kentucky-Illinois fluorspar district.

the district extends over six counties, but the principal mines are in Crittenden and Livingston counties. The producing district is approximately 40 miles square.

The Illinois portion of the district may be reached via Illinois Central Railroad, of which a branch line terminates at Rosiclare, or via State Highway No. 34 to Elizabethtown and Golconda from Harrisburg, 25 miles north.

HISTORICAL SUMMARY

"Attention seems to have been first attracted to the Kentucky-Illinois district by the occurrence of the brilliantly colored fluorite. In early American geologic literature there are numerous references [a] to this fluorspar, or "fluate of lime," as it was then called. It was usually noted as coming from Shawneetown, Illinois, as that was the nearest town of any size. The galena which occurs associated with the fluorite was probably noticed very early in the nineteenth century, but it was not until some years after the settlement of the country that any serious attempt was made to mine it. The first important mining venture seems to have been that of a company headed by President Andrew Jackson, which undertook development near the site of the present Columbia mines, in 1835, in Crittenden County, Kentucky. In Illinois fluorspar seems to have been first discovered in place in 1839 when it was encountered with galena in sinking a well on the Anderson farm on what is now the property of the Fairview (Franklin) Fluorspar Company."[1]

In 1842 Mr. William Pell opened the Pell mine, now part of the Rosiclare mine, and in the late forties mines farther south on the same vein were opened. However, galena was the object of all the early prospecting and mining, the associated fluorite being a valuless gangue which accumulated on the dumps. The demand for lead during the Civil War stimulated mining and a limited demand for lump fluorite as a flux in the cupola iron furnaces sprang up. Lead mining continued until the early seventies, the galena being smelted at the mines.

About 1870 fluorspar was ground in buhrstone mills, and in 1878 "gravel spar" too small for "lump" was shipped. Mining on a small scale continued through the eighties and nineties and the old dumps of the lead mines were worked over for fluorspar. It was not until about 1900, however, that fluorspar mining assumed important proportions.

Until 1909, the Rosiclare mine, which has since been the largest producer in the district, was operated only on a small scale. Its daily production, mainly "gravel spar" but some "lump," did not exceed 25 tons. This was barreled

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[a] Am. Jour. Sci., 1st ser., vol. 1, 1818, pp. 52-53; vol. 2, 1820, p. 176; vol. 3, 1821, p. 243.
Schoolcraft, H. R., A view of the lead mines of Missouri, 1819, p. 191.
Cleveland, Parker, Mineralogy, 1822, p. 202.
Brush, J. G., Am. Jour. Sci., 2d ser., vol. 14, 1852, p. 112.

[1] Bain, H. F., The fluorspar deposits of southern Illinois: U. S. Geol. Survey, Bull. 255, p. 12, 1905.

and hauled on a narrow-gauge track to the Ohio River, transhipped by steam packet up-river to Evansville, Indiana, and there transferred to railway cars. Until 1919 all spar was shipped from the district by boat, but in July of that year the branch of Illinois Central Railroad serving Golconda was extended to Rosiclare. Thereafter there were no shipments by water except from the mines near Cave in Rock.

After several years of exploratory work the Hillside shaft was started in 1919. Construction of the mill was begun late in 1920 and production began in April, 1922.

In November, 1923, the Extension and Annex workings (Pls. I and II) on the southern portion of the Rosiclare vein, operated by the Franklin Fluorspar Company, were flooded by a large flow of water. The water, which came apparently from Ohio River, was struck in a raise from the 200-foot level of the Extension shaft near the Anderson well shaft. When the workings were shut down, 3000 gallons of water were being pumped per minute from them.

The flooding of the Rosiclare mine in January, 1924, was a more serious disaster. Before the 620-foot level of the Rosiclare was far advanced, about 1200 gallons of water were being pumped per minute. This included an overflow of 500 to 600 gallons from the Franklin No. 4 workings to the south, which had been recently flooded. As the 620-foot level was advanced northward, successive flows of water were encountered. Some of them bubbled up like springs in the bottom of the drift, and other large flows were struck by drill holes in the face. Large flows of water were also encountered in driving the 720-foot level northward. As a result of continuous wet weather a cave-in from the surface at a point 2000 feet north of the Rosiclare plant shaft occurred in December, 1923. The caved material filled the 500-foot level and stopes and dammed the water in this level. Eventually the water saturated the dam and overflowed into lower workings. Unusually high water in Ohio River increased the inflow from the Fairview workings and made the situation worse. The pumps were supplemented by bailing, and by January 19, 1924, 3400 gallons of water per minute were being raised. The pumps could not stand the continuous heavy load, and on January 20 they were stopped after as much equipment as possible had been removed. Since then there has been no production from the Fairview-Rosiclare vein, and the output has come mainly from the Hillside and Daisy mines near Rosiclare (Pls. I and II) and from the Spar Mountain mines near Cave in Rock. (Pls. I and VII.)

EARLIER GEOLOGIC REPORTS

The principal geologic reports regarding the Illinois portion of the district are:

1. Bain, H. Foster, The Fluorspar Deposits of Southern Illinois: Bull. 255, United States Geological Survey, 1905. Deals mainly with the fluorspar deposits.
2. Weller, Stuart, and associates, The Geology of Hardin County: Illinois State Geological Survey, Bulletin 41, 1920. Deals mainly with the sequence of rock formations, the manner in which they have been folded and fractured, and the fossils which they contain and which can be utilized in identifying particular formations. It includes a chapter on the fluorspar deposits by L. W. Currier and a map showing the geologic formations and the principal faults or fracture zones.

The principal reports regarding the Kentucky portion of the district are:

1. Ulrich, E. O., and Smith, W. S. Tangier, The Lead, Zinc and Fluorspar Deposits of Western Kentucky. Professional Paper 36, United States Geological Survey, 1905.
2. Fohs, F. Julius, Fluorspar Deposits of Kentucky, Bulletin No. 9, Kentucky Geological Survey, 1907.
3. Currier, Louis W., Fluorspar Deposits of Kentucky, Kentucky Geollogical Survey, series 6, vol. 13, 1923.

TYPES OF FLUORSPAR DEPOSITS

The operators commonly class the fluorspar deposits of Illinois as (1) veins, and (2) blanket deposits. The two classes differ in attitude, in texture, and to some degree in mineral composition. The classification is a convenient one and is followed in this report.

The vein deposits, typically developed near Rosiclare, have been the source of the larger part of the Illinois production. They are steeply inclined, sheet-like deposits that cut across the nearly flat-lying sedimentary beds of the region against which they have prevailingly sharp contacts (Fig. 3). It is clear that they were deposited along steeply inclined fault planes and fracture zones. Whether the vein material filled gaping fissures, was introduced into narrow fractures under pressure sufficient to expand the fractures, or was deposited by replacement is considered elsewhere in this report (p. 14).

The blanket deposits, of which the deposits at Spar Mountain and Lead Hill (Pls. I and VII) are typical, are flat-lying or nearly so and follow in a general way the bedding of the sediments in which they occur. However, they are not flat veins but are deposits formed by the solution and removal of limestone and the immediate deposition of fluorite and associated minerals in its place—a process known as "replacement." The evidence that they were formed by replacement and not by the filling of flat fractures is given elsewhere (p. 49).

CHAPTER II—VEIN DEPOSITS

DISTRIBUTION

The vein deposits of fluorspar lie in the western part of Hardin County and the eastern part of Pope County (Pl. I). The bulk of the Illinois production formerly came from a single large vein, the Fairview-Rosiclare, near the town of Rosiclare, but since 1924, when the workings in that vein were flooded, the Hillside and Daisy mines have been the principal producers (Pls. I and II). Fluorite veins scattered as far as ten miles north of Rosiclare have been worked but production from these outlying veins has been relatively insignificant.

VEIN WALLS

The vein deposits of the Rosiclare region cut indiscriminately through sandstone, shale, and limestone beds, against all of which the contacts of the vein material are prevailingly sharp (Fig. 2). As limestones might be expected to be most readily corroded or replaced by vein-forming solutions, the contacts of the veins against limestone beds were studied with particular care.

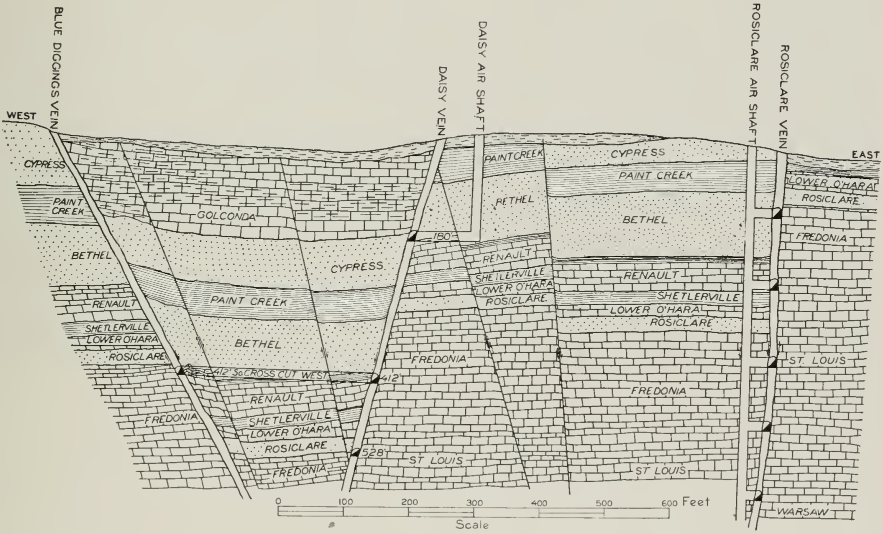

Fig. 2. Diagrammatic cross-section showing stratigraphic and structural relations in the vicinity of Rosiclare.

The relations in the Hillside mine are typical. In this mine the Hillside vein is at least 14 feet wide and consists of calcite and fluorite in proportions approximately three to one. The east wall of the vein is well exposed at the shaft cross-cut on the 350-foot level where the contact of vein material against the limestone wall is as sharp as a knife-edge, and limestone fragments in the vein material are sharply angular. Numerous specimens from the dumps of the Hillside mine show similar sharp contacts with no textural change in the limestone near the contact. Sharp contacts of the Daisy vein against limestone walls are clearly shown in the Daisy mine (Fig. 3) and specimens from the Daisy dumps exhibit similar relations.

FIG. 3. Daisy vein, about 3 feet wide, in the top of the 412-foot level of the Daisy mine, looking north toward the main shaft from near cross-cut. The sharp contacts between the vein material, mainly calcite, and the limestone of the foot wall (right) and the angular, ragged limestone fragments in the vein are well shown. The hanging wall (left) is a smooth, slickensided surface along which there has been movement since the vein was formed. The irregular dark patch near the center of the vein is a stain produced by seepage of petroleum out of the vugs in the vein.

EVIDENCE OF REPLACEMENT

Although the contacts of the vein material against the country rock are prevailingly sharp, exceptions to the rule were noted at two places in the Hillside mine.

One of these places occurs on the 170-foot level where the cross-cut to the shaft cuts the vein (Pl. IV, p. 72). The typical coarse vein material grades through three to four feet of finely banded fluorite-bearing material into the limestone forming the east wall. Forty bands occur in a width of six inches of this material and in places there are as many as twelve bands to the inch. Microscopic study of thin sections revealed that the lighter bands are wholly fluorite and the darker bands are a mixture of fluorite, quartz, ferruginous calcite, and galena, named in the order of their usual relative abundance. Most of the banded material is slightly oxdized, the ferruginous calcite being stained yellow with limonite. The gradation of banded material into typical coarse vein material indicates that the formation of the vein and of the banded material probably proceeded simultaneously. The banding is not parallel to the vein; near the vein it diverges at an angle of about 35°, and six inches farther away it is nearly perpendicular to the vein. The banded material extends farthest from the vein where calcite veinlets, one-sixteenth to one-eighth of an inch wide, extend into the limestone (Fig. 4). Traces of the position of these veinlets are still recognizable in the banded material for three or four inches away from the limestone. The limestone adjacent to the banded material is dark gray and medium grained. Some of the calcite in it is ferruginous and weathers buff like that in the banded material.

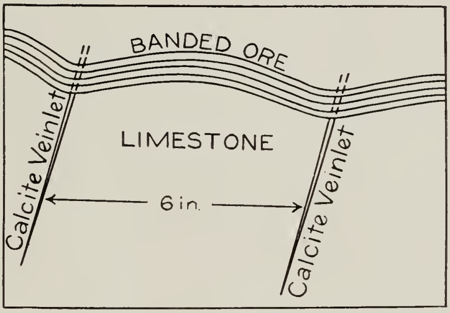

Fig. 4. Diagrammatic sketch showing how replacement banding extends farthest into the limestone along small fractures now sealed with calcite, as exposed at shaft cross-cut on 170-foot level in the Hillside mine.

Banding of the sort just described is now generally regarded by economic geologists as the result of rhythmic deposition of mineral matter during replacement. Mineralizing solutions starting from the Hillside fault diffused into the limestone of the east wall, dissolving the limestone and immediately depositing fluorite and other minerals in its place. The greater advance of the banded material along veinlet-filled fractures (Fig. 4) indicates that the penetration of the limestone was facilitated by minor fractures. The process is similar to that by which the bedded, rhythmically banded fluorspar deposits at Lead Hill and Spar Mountain were formed.

A second place showing replacement occurs on the 350-foot level, 390 feet north of the cross-cut to the main shaft. A network of veinlets of white, opaque calcite with a little purple fluorite sharply cuts brownish-gray fine-grained limestone. Subsequent to their formation, some of the limestone between the veinlets has been partially replaced by white quartz in hexagonal crystals variously oriented. At some places the limestone between the quartz crystals has been recrystallized into a white, very fine-grained calcite aggregate. Some of the quartz forms rosettes of radiating crystals. This replacement of limestone by quartz appears to be later than the fluorite mineralization, inasmuch as no fluorite was deposited with the quartz.

The phenomena at both places are of little economic importance, but they are evidence of a replacement process. The data revealed in underground workings and in mine dumps of the Illinois fluorite veins as now accessible to study would probably influence few geologists to attritube to replacement a large rôle in the process of the formation of the veins. In fact, most geologists who have studied them have regarded them as fillings along fault fissures. J. E. Spurr has interpreted them as "vein-dikes," the products solely of injection of an "ore magma" along fault zones.[1] But the key to their origin may be found in the Kentucky portion of the district, which is not covered in detail in this report. Essentially all of the known Kentucky deposits are steeply inclined veins, most of which follow well defined faults; blanket deposits like those at Spar Mountain in Illinois are not known. They exhibit strong evidence of the importance of replacement as a mineralizing process, which may be summed up as (1) ragged limestone remnants, (2) stylolitic structure, and (3) diffusion banding.

RAGGED LIMESTONE REMNANTS

Although much of the intergrown calcite and fluorite of the veins in the Hudson mine near Salem, Kentucky, shows sharp contact with the prevailing limestone wall-rock as well as with some of the angular limestone fragments enclosed in vein material, many specimens on the dump show limestone with exceedingly ragged and irregular contacts against vein material (Fig. 5). Such outlines cannot conceivably have been produced by fracturing alone but indicate that the limestone country rock has been partly replaced by the calcite. Similar ragged, irregular limestone masses in vein material are common also in the Lafayette and Haffaw mines near Mexico, Kentucky. In the Lafayette mine it was especially evident that replacement had been an important if not the dominant process of mineralization, because limestone fault breccias in all stages of destruction by replacement were noted. At many places both angular and ragged limestone fragments occur in a matrix of vein material. Different types of the limestone clearly differed in their susceptibil-

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[1] Spurr, J. E., Engineering and Mining Journal, vol. 122, p. 736, 1926.

ity to replacement; fragments of dense, fine-grained limestone are often angular whereas fragments of coarser limestone have become ragged as a result of partial replacement. At some places both angular and ragged limestone fragments surrounded by calcite and fluorite are impregnated with fine sphalerite, clearly a result of replacement. At one place in the Franklin mine near Marion, Kentucky, the vein is a fractured zone about 20 feet wide comprising several bands or horsts of dark-colored limestone up to three feet wide separated by mineralized material which at some places consists wholly of calcite and fluorite but elsewhere is studded with limestone fragments. Some of the limestone fragments, especially the larger ones, are sharply angular, and others are raggedly irregular, typical replacement remnants.

FIG. 5. Rock specimen from dump of Hudson Fluorspar Mine, near Salem, Kentucky, showing remnants of dark gray limestone surrounded by vein calcite. The ragged contacts indicate that the limestone has been partly replaced by the calcite.

STYLOLITIC STRUCTURES

The stylolitic structure in the vein material or in mixtures of the limestone country rock and the vein material constitutes a second line of evidence of the importance of the replacement process in formation of the veins. Stylolitic partings are jagged sutures developed characteristically in limestone and dolomites and in marbles (Fig. 6) and consist of narrow seams of clayey material bordered on both sides by limestone which may differ in texture, color, composition, and more rarely in attitude on the opposite sides. Stylolitic partings are formed by the gradual dissolving of the calcium and magnesian carbonate of two limestone beds along their mutual contact without the formation of any open spaces, the pressure of overlying beds facilitating solution and preventing the formation of openings.[2] The clayey impurities originally contained in the dissolved limestone become concentrated to form the dark band marking the jagged parting.

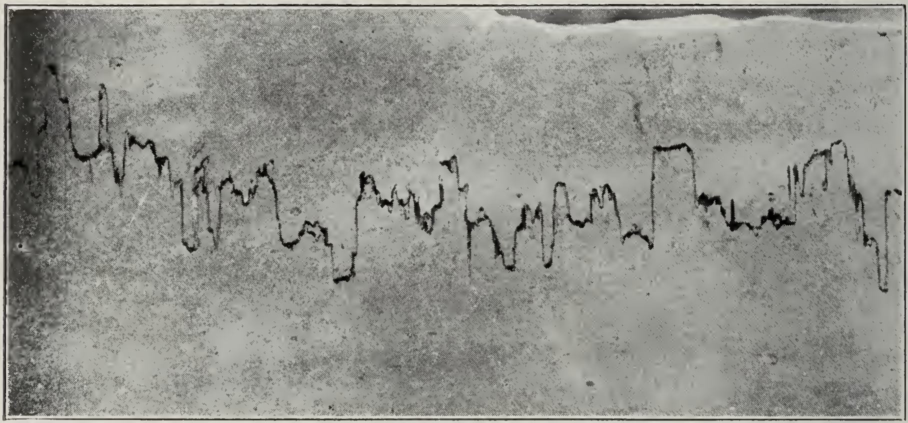

FIG. 6. Typical stylolite seam in Salem limestone. About one-half natural size. *Courtesy Paris B. Stockdale.*

Typical stylolitic structure is very commonly developed in the limestones cut by the Kentucky fluorspar veins. Some stylolitic partings can be traced continuously without deflection from the limestone into vein material, others, at one place bordered on both sides by limestone are a short distance away bordered on one side by limestone and on the other by vein material (Fig. 7), and others separate a band of gray limestone from white vein calcite (Fig. 8). The stylolitic partings composed of relatively insoluble clayey material have served as barriers to protect the limestone from replacement. The same conditions exist in Illinois (Fig. 9).

A more advanced stage of mineralization is illustrated in a specimen from the Cullen mine, Kentucky, in which one stylolitic parting traverses a

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[2] Stockdale, Paris B., Stylolites: Their Nature and Origin, Indiana University Studies No. 55, Vol. IX, 1922.

FIG. 7. Stylolitic structure in gray limestone mineralized by new calcite. The stylolite crosses areas both of limestone and of mixed limestone and vein minerals, indicating that the vein calcite replaced the limestone. At some places the stylolitic parting of relatively insoluble minerals limited replacement so that on one side of the stylolite is vein calcite and on the other is limestone. About natural size. Cullen Mine, near Salem, Kentucky.

Fig. 8. Coarsely crystalline, white vein calcite separated by irregular stylolitic partings from gray limestone. The replacement of limestone by calcite was checked by the relatively insoluble materials of the stylolitic bands. About one-third natural size. Cullen Mine, near Salem, Kentucky.

Fig. 9. A stylolitic parting separating a light colored band of calcite and fluorite from brownish-gray limestone. The calcite and fluorite band, which was developed by selective replacement of the light gray limestone, terminates abruptly at the stylolitic parting. About three-fourths natural size. Specimen from dump of the Hillside mine, Rosiclare, Illinois.

considerable area of vein calcite and others bound unreplaced limestone remnants (Fig. 10). A still more advanced stage of mineralization in which only minor remnants of limestone remain in a mass of calcite and fluorite is illustrated in a specimen from the Nancy Hanks mine, near Salem, Kentucky. This specimen (Fig. 11) contains many stylolitic partings along one side of which limestone remnants are commonly preserved. The persistence of some of the stylolitic partings across the whole specimen indicates that before replacement the limestone was not a jumble of diversely oriented fragments although it was doubtless somewhat fractured. The extreme of limestone mineralization by replacement is perhaps represented by a specimen from the dump of the Hillside mine in which a stylolitic parting traverses a calcite and fluorite aggregate and minute remnants of limestone remain only at a few prongs of the parting.

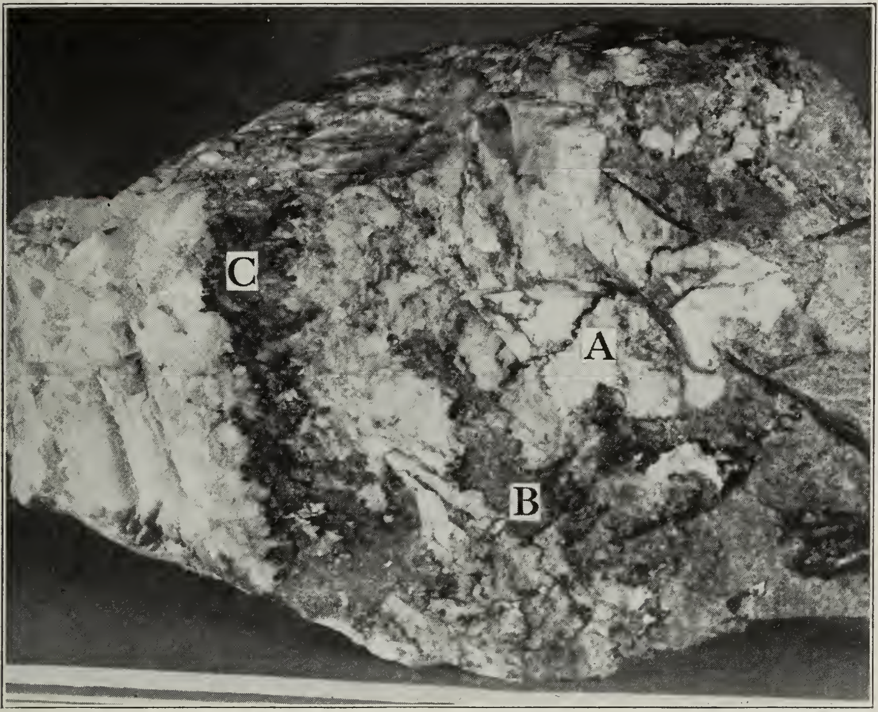

FIG. 10. A more advanced stage of replacement of stylolitic limestone than that shown in figures 7 and 9. At A a stylolitic parting traverses vein calcite and at B and C unreplaced limestone remnants are separated from the vein minerals by stylolitic partings. Specimen is about 10 inches long. Cullen Mine, near Salem, Kentucky.

FIG. 11. Nearly complete replacement of stylolitic limestone by vein calcite and fluorite. At some places the relatively insoluble stylolitic partings are all that is left of the original limestone; elsewhere small remnants of limestone usually bounded by stylolitic partings remain. Nancy Hanks Mine, near Salem, Kentucky.

DIFFUSION BANDING

It has been mentioned that the banded fluorspar which borders the Hillside vein at one locality in the Hillside mine, in Illinois, is believed to be due to rhythmic precipitation during replacement, and also that the banded blanket deposits of Spar Mountain are believed to have an analogous origin (p. 15). In the Cullen mine near Salem, Kentucky, material similar in texture to the banded fluorite of Spar Mountain, Illinois, but consisting of

FIG. 12. Banded ore from dump of Cullen Mine near Salem, Kentucky. The light bands are fluorite and the dark bands are sphalerite. They are interpreted as the result of rhythmic deposition during replacement of limestone. Specimen is 10 inches long.

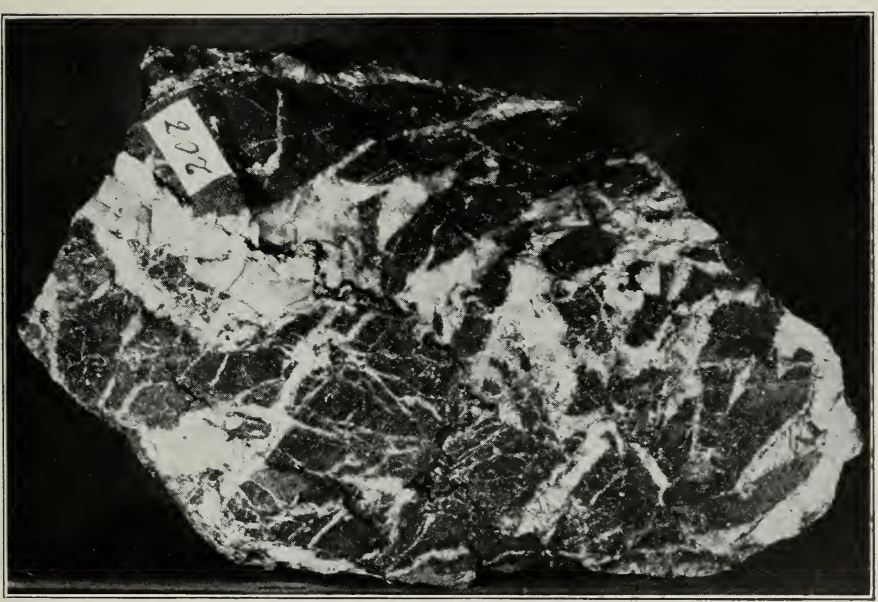

FIG. 13. Associated vein calcite and gray limestone from Lafayette Mine, near Mexico, Kentucky. The black stylolitic parting traversing the specimen shows that the calcite was deposited largely by replacement although the general appearance suggests a limestone breccia whose interspaces have been filled with calcite. Specimen is about 10 inches across.

alternate bands of fluorite and sphalerite (Fig. 12), forms part of the mineralized fault zone or vein, according to Mr. A. H. Reed of Marion. This banding is also attributable to replacement.

SUMMARY

The combined evidences of ragged remnants of limestone in the veins, of preserved stylolitic partings, and of repeated banding seem to indicate clearly that the process of replacement has played a very important rôle in vein formation both in Kentucky and in Illinois. Close study of some ores that resemble limestone breccias in which the interspaces between fragments are filled with vein minerals reveals that they have been formed by replacement as shown by the preservation of black stylolitic partings (Fig. 13).

Fig. 14. Vein breccia from dump of Hillside Mine, near Rosiclare, Illinois. A product of selective replacement of the small fragments of the matrix and of filling of open spaces. The larger fragments have not been replaced. Specimen about 10 inches across.

It must not be inferred, however, that no filling of open spaces took place in the process of vein formation. In some vein breccias the matrix and smaller fragments are more readily replaced than are the larger fragments, but filling of open spaces between fragments doubtless also took place. It should be pointed out also that, because of the variety of beds constituting the vein walls, fragments of several sorts of rocks may be jumbled together in a vein breccia, and of these some may be easily replaceable and develop ragged outlines while others may be resistant to replacement and retain their angular outlines (Fig. 14).

Minerals of the Veins

The following minerals have been noted in the veins:

Primary vein minerals
Fluorite }
Calcite } Dominant
Ferruginous calcite
Quartz
Galena
Sphalerite
Pyrite
Chalcopyrite
Oil and bitumen

Secondary vein minerals
Barite
Gypsum
Malachite
Cuprite
And many others

FLUORITE

Fluorite is the principal mineral of economic value in the vein deposits and ranks next to calcite in abundance. As it is dealt with so fully in later sections of the report, it is not discussed here.

CALCITE

Calcite is the most abundant mineral in the veins. Most commonly it occurs intimately associated with fluorite and in such associations it is white to light gray and opaque. At one place in the Hillside mine small amounts of pale pink calcite were noted. A few calcite crystals are three to four inches across, but crystals with diameters of one to two inches are more common. In the discussion of the mutual age relations of fluorite and calcite (pp. 31-37) it is pointed out that calcite was not only commonly the first vein mineral deposited but that in many cases it was also the last mineral deposited, as it is found as a snow-like incrustation upon crystals in vugs (p. 39). The calcite in the vugs is commonly scalenohedral in form.

QUARTZ

Quartz is a minor primary mineral in the fluorite veins, and where present it was commonly deposited late in the mineralization, often occurring as scattered small crystals in vugs. Vugs in a specimen from the dump of the Hillside mine are lined with scalenohedral calcite crystals in and on which are small crystals of chalcopyrite, both coated in places with small crystals of colorless quartz. The sequence of mineral deposition in this specimen may be diagrammatically represented as in A, figure 15. Some crystals of colorless to brownish quartz up to four millimeters in diameter are embedded in opaque white calcite and colorless fluorite in numerous specimens collected from the Hillside dump. The sequence of mineralization in these specimens may be diagrammatically represented as in B, figure 15.

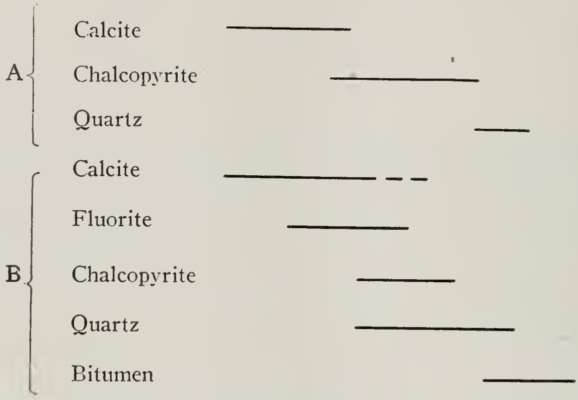

Fig. 15. Diagrammatic representations of the sequence of mineral deposition in specimens from the Hillside Mine.

Crystals of clear colorless quartz up to one-fourth of an inch long are indented slightly in the faces of the cubical fluorite crystals up to half an inch across in a specimen in the Hillside mine collections.

GALENA

Galena is the most common sulfide in most of the veins. It is clearly an original vein mineral, but in the main it crystallized later than most of the calcite and fluorite, as is shown by its usual distribution in veinlets traversing these minerals—particularly fluorite. Its usual mode of occurrence is well illustrated in the stopes north of the shaft on the 450-foot level of the Hillside mine, where bands of galena traverse the white fluorite in the central portion of the 30-foot vein. The galena bands are nearly parallel to the vein, are usually less than an inch wide and are rarely continuous for long distances. A little chalcopyrite is intergrown with the galena and is presumably of the same age. The occurrence of galena in veinlets shows that its distribution was controlled by fractures within the vein. However, the walls of the galena veinlets are neither regular nor parallel, as is characteristic of fissure fillings, but the characteristic cubical outline of galena exists against the fluorite. They are interpreted as replacement veinlets along zones of minor fracturing. Once established they became planes of weakness and later movement along some of them crushed the galena to form the variety known as "steel" galena.

Specimens from the Hillside dump show sharp-walled veinlets of opaque white calcite, colorless to pale purple fluorite, and galena traversing limestone. Though clearly a part of the vein filling the galena is not evenly distributed but forms irregular, tortuous, and somewhat discontinuous veinlets in or between the calcite or fluorite or between them and the limestone walls. The characteristic cubical outline of galena exists against calcite, fluorite, and limestone.

The galena is believed to have replaced calcite and fluorite late in the mineralization process, being deposited from solutions that penetrated small fractures in those minerals.

Currier in his report on the fluorspar deposits gives photomicrographs of very minute replacement veinlets of galena in fluorite and also shows replacements of calcite by galena[3] (Figs. 16 and 17).

Rounded surfaces of galena at a few places are evidence of solution, but this is attributed to the action of ground waters operating long after the veins were formed.

The galena content is extremely variable from vein to vein and from place to place in the same vein. In the Rosiclare vein, for example, it is on the average probably twice as abundant as it is in the Daisy vein.

SPHALERITE

Sphalerite is generally not as widespread in the veins as is galena, but at some places it is abundant. It was particularly abundant in the Fairview workings. It occurs in the veins and also to a minor degree as a replacement of the wall rock. It appears to be about contemporaneous with most of the fluorite. In the walls of a cavity in one specimen from the Fairview dump, characteristic crystals of sphalerite, fluorite, and calcite, occur side by side with no one mineral coating the others. In another specimen sphalerite forms a net work of small veinlets in calcite, but the boundaries of the veinlets are often crystal faces of calcite. This suggests that the calcite was ruptured while it was crystallizing and that the sphalerite was deposited in the ruptures. A specimen in the Rosiclare mine collections has vugs lined with crystals of sphalerite, purple fluorite, and galena, side by side and no one coating the others but all are coated by scalenohedral crystals of white calcite. The alternate diffusion bands of fluorite and sphalerite in the specimen from the dump of Cullen Mine, Kentucky, (Fig. 12, p. 23) seem to indicate essentially contemporaneous deposition of the two minerals at that place.

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[3] Currier, L. W., Part V, Economic Geology, "Geology of Hardin County," Illinois State Geol. Survey, Bull. 41, Pls. II B and II D, 1920.

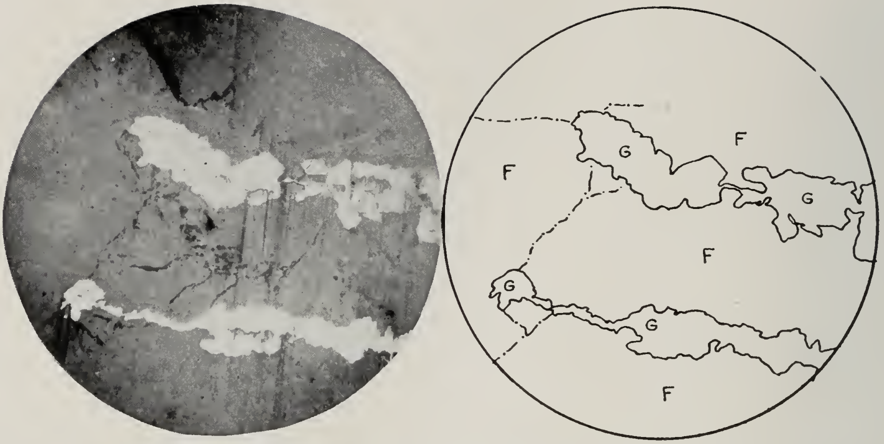

Fig. 16. Galena (G) replacement veinless in fractured fluorite (F). (After Currier, L. W., Illinois State Geol. Survey Bull. 41, Pl. II-B, 1920.)

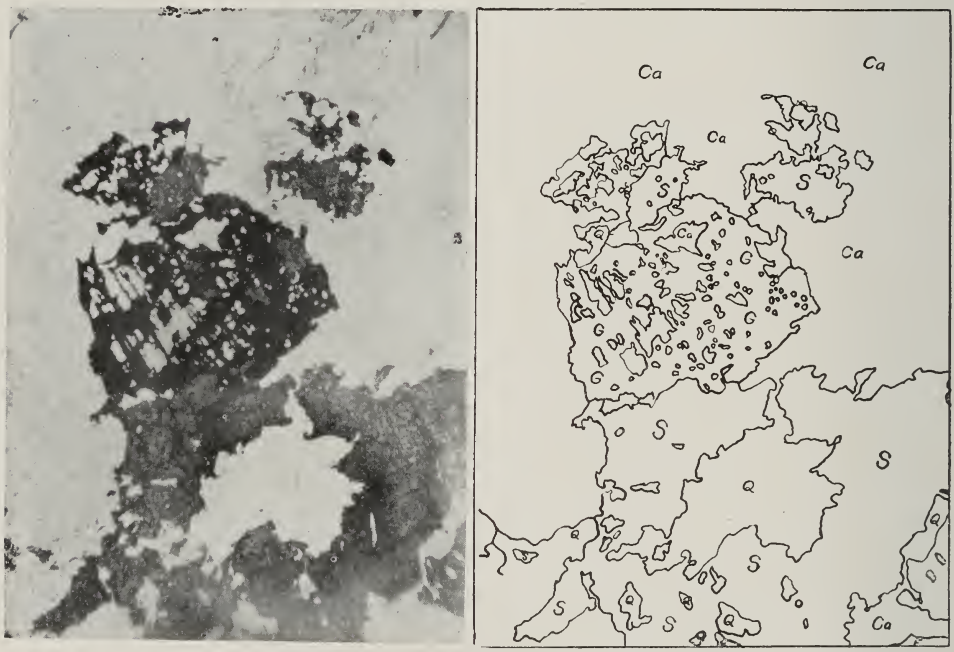

Fig. 17. Galena (G) replacing calcite (Ca) along twinning directions of the latter, and thereby developing a "lattice" structure. The galena includes small grains of sphalerite (S). Large sphalerite masses contiguous to the galena are seen replacing calcite; it shows a slight tendency to follow the calcite, and in other areas develops this feature markedly. Quartz and fluorite (F) are included by the sphalerite, the quartz being replaced by very small extensions of sphalerite. Fluorite appears replacing calcite, but no other mineral. A general fracture zone is seen—about one inch wide in the figure—which contains small grains of all the minerals. Sphalerite does not appear to include patches of galena, though the reverse of this is common. (X-25.) (After Currier, L. W., Illinois State Geol. Survey Bull. 41, Pl. II-D, 1920.)

PYRITE

Pyrite is rather widespread in the fluorite veins but is quantitatively subordinate except in a few places. Some pyrite clearly crystallized before deposition of fluorite was completed but where pyrite is most abundant it appears to have been deposited after—perhaps long after—the fluorite mineralization. Two instances of deposition of pyrite after older fluorite and accompanying younger fluorite are described on page 41.

In a vug on the 350-foot level of the Hillside mine, pyrite coats cubical faces of colorless fluorite but none occurs within the fluorite or indenting its surfaces, so that it is clearly later—possibly much later—than the fluorite. Pyrite unassociated with other minerals coats a narrow, straight fracture in gray fluorite in a specimen from the Rosiclare mine, showing clearly that fracturing intervened between the deposition of fluorite and pyrite. In the wall of the Argo vein a cavity said to be 60 feet long, 30 feet high, and 15 feet wide was lined first with pyrite of radiating structure, on which was deposited a layer of calcite and then a thin second coating of pyrite. This pyrite may have no connection with the fluorite mineralization. A second and even larger cavity in the Argo mine was lined with half-inch crusts of radial pyrite on which crystalline calcite was deposited. Pyrite stalactites observed on the dumps of the Fairview-Rosiclare vein probably came from similar cavities.

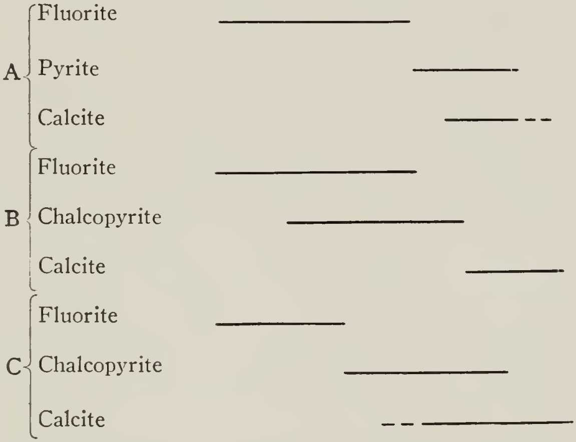

FIG. 18. Diagrammatic representations of the sequences of mineral deposition in specimens from the Hillside Mine.

Limonite stalactites abundant on the dump of the Stewart mine probably resulted from the oxidation of abundant pyrite. A specimen in the Hillside mine collections, apparently representing part of a finger-like projection from the wall of a vug, has a core of white to purple fluorite coated with a one-sixteenth inch layer of pyrite in turn coated with a one-fourth to one-half inch layer of gray calcite inclosing a little pyrite. The sequence of mineral deposition is diagrammatically represented in A, figure 18.

The relations indicate that deposition of pyrite was sparse but rather widespread in the late stages of fluorite mineralization. Pyrite was deposited abundantly in a few places after fluorite deposition had ceased, but such deposits may be wholly unrelated to the fluorite mineralization.

CHALCOPYRITE

Chalcopyrite is a minor but fairly common component of the veins. No attempt is made to recover it in the fluorspar milling. Captain A. B. Thomas reports finding a four pound mass of chalcopyrite in white fluorite on the 250-foot level of the Hillside mine, but such an occurrence is exceptional. Commonly this sulfide occurs in small crystals, seldom exceeding one millimeter in diameter, in vugs. In some instances (p. 40) the directional influence of gravity has been operative during the deposition of chalcopyrite as shown by its greater abundance on surfaces that were gently inclined than on those that were steeply inclined.

In a fairly typical specimen from a vug in stopes above the 450-foot level of the Hillside mine, tetrahedral crystals of chalcopyrite seldom more than one millimeter in diameter are inclosed within pale blue-green fluorite and are also indented in the cubical fluorite faces. Small crystals of calcite have been deposited over some of the fluorite and chalcopyrite and can be cleanly stripped off of the fluorite. The sequence of mineral deposition may be diagrammatically represented as in B, figure 18. In another specimen from the Hillside vein chalcopyrite occurs as scattered crystals *on* but not *in* crystals of blue-green fluorite. Calcite coats both minerals and in places completely incloses chalcopyrite. The sequence of mineral deposition may be diagrammatically represented as in C, figure 18.

BARITE

Barite is occasionally found in the fluorspar veins. In the Hillside mine, according to Mr. E. C. Reeder, Superintendent, the only barite of consequence occurred in a nearly pure, compact, crystalline mass, 3 to 4 feet wide in stopes within 60 feet of the surface. The only occurrences noted by the writer were in specimens in the collections at the Hillside and Rosiclare mines. Two specimens in the Hillside collections show cubical crystal faces of white fluorite some of which are coated with rosettes of small barite blades intergrown with a few scalenohedral crystals of calcite. The calcite and barite are never inclosed, even partially, by the fluorite. The deposition of this barite has been influenced by gravity (p. 40). It was deposited after fluorite deposition had ceased but how long afterward is problematical. A specimen in the Rosiclare mine collections, taken from a vug in the Rosiclare vein, also shows blades of barite coating fluorite. The depths from which these cabinet specimens came were not recorded.

Barite was not noted by the writer in any of the ores from the deeper portions of the veins. All available evidence indicates that in the veins as in the blanket deposits it was deposited after—perhaps long after—deposition of fluorite had ceased. Its greater abundance near the surface suggests that it was deposited from cool ground waters circulating through the veins and their surrounding rocks.

GYPSUM

Gypsum, according to Captain A. B. Thomas, former General Manager of the Hillside mine, was found in good sized crystals in pockets in the upper levels of that mine. It is unknown in the deeper levels of that or other mines. It was probably deposited from circulating ground waters long after the formation of the fluorspar veins.

CUPRITE AND MALACHITE

Cuprite and malachite are oxidation products of chalcopyrite in the upper portions of the veins but are not abundant or conspicuous. They commonly occur together, the cuprite occupying essentially the position of the chalcopyrite from which it was derived and the malachite surrounding it, staining the bordering minerals along cleavage planes, and wandering some distance from the cuprite.

RELATIONS BETWEEN CALCITE AND FLUORITE

The mutual relations of the two principal vein minerals, calcite and fluorite, are especially significant as they bear upon the origin of the ores. In general, calcite is more abundant nearer the walls and fluorite more abundant nearer the central portion of the veins; calcite tends to become more abundant and fluorite less abundant where the veins fork and pinch and show signs of playing out near the ends of the drifts. To these ruling tendencies there are of course some exceptions.

In one of the wider portions of the vein in the stopes above the 350-foot level and about 75 feet north of the shaft cross-cut in the Hillside mine (Pls. II and IV) the west or hanging wall is a slickensided fault-plane which cuts the vein material, and was therefore, developed after the mineralization. Next to the fault occurs fourteen feet of pure gray fluorite beyond which is fifteen feet of calcite cut by fluorite veinlets which approximately parallel the vein and several of which carry galena near their centers. The east wall of the vein is not exposed.

The occurrence of fluorite veinlets is well shown at two other places, respectively 750 and 800 feet north of the shaft cross-cut on the 250-foot level of the Hillside mine (Figs. 19 and 20). In the stopes above the 350-foot level, 530 feet south of the shaft cross-cut of the Hillside mine, 15 feet of the vein material was exposed with neither wall showing. Part of the vein material is an irregular calcite-fluorite mixture traversed by a ramifying network of fluorite veinlets. Analogous occurrences exist elsewhere in the same mine (Figs. 21 and 22). It is significant that the walls of the fluorite veinlets are not parallel and many of them show crystal faces of calcite projecting into the fluorite.

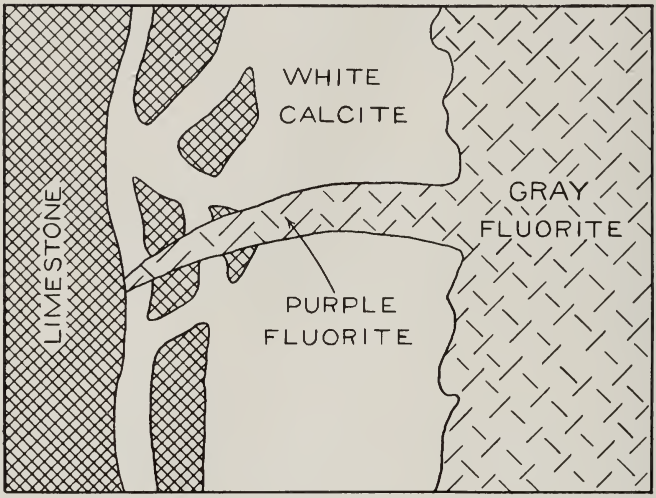

Fig. 19. Diagrammatic sketch showing veinlet of fluorite traversing vein calcite and limestone inclusions. The main vein is here 3 feet wide with a central 2½ feet of gray fluorite. Hillside Mine, 250-foot level, 750 feet north of shaft cross-cut.

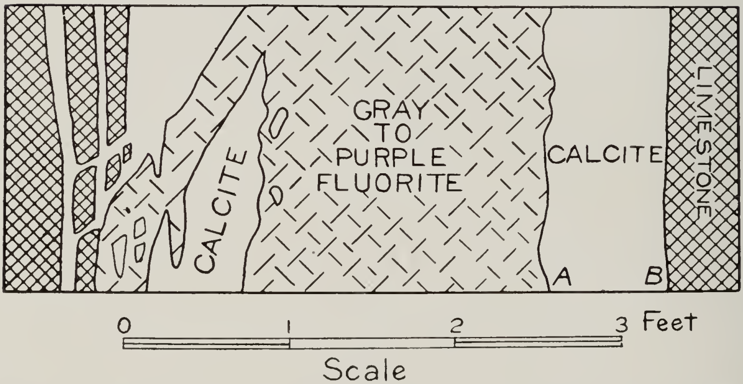

Fig. 20. Diagrammatic sketch showing entire width of vein 800 feet north of shaft cross-cut on 250-foot level of the Hillside Mine. Fluorite occupies the center of the vein, branches into the calcite, and encloses a few angular fragments of calcite. The contact (A) between fluorite and calcite is irregular, and what appear to be straight crystal faces of calcite project into the fluorite. The contact between limestone and calcite (B) is a tight "frozen" contact.

FIG. 21. Calcite vein material traversed by irregular veinlets of fluorite (black). Hillside Mine, 350-foot level, about 250 feet south of the shaft cross-cut. The field shown is about 4 feet across.

FIG. 22. Network of veinlets of purple fluorite (dark gray) traversing calcite vein material and enclosing regular masses of calcite. Hillside Mine, 250-foot level, 325 feet north of shaft cross-cut. The field shown is about 5 feet across.

In contrast to the occurrence of fluorite veinlets traversing calcite, at other places fluorite of entirely similar appearance is intimately intermixed with calcite, as is well shown 290 feet north of the shaft cross-cut on the 450-foot level of the Hillside mine, where unusually large crystals of calcite, some of them six to eight inches across, are inclosed by white fluorite. Many of the contacts between the two minerals are straight, clean-cut, crystal faces of calcite. Similar mixtures of calcite and fluorite occur about 650 feet north of the shaft cross-cut on the 350-foot level where the largest calcite crystals are about three inches across and the sharp, straight crystal faces of much of the calcite against fluorite are clearly shown (Fig. 23).

Fig. 23. Mixture of calcite and fluorite 650 feet north of the shaft cross-cut, 350-foot level of the Hillside mine. Note the sharp, straight crystal faces of calcite (light) against fluorite (dark). The largest calcite crystal is three inches in diameter. The calcite of such crystals obviously has not been attacked by fluorite-bearing solutions or the crystal faces would have been impaired.

A careful inspection of the materials cast on the Hillside dump showed that the contacts between calcite and fluorite are prevailingly straight crystal faces—often rhombohedral faces—of calcite. No ragged, irregular contacts of calcite against fluorite were seen. A microscopic study of specimens from the Hillside mine confirmed the field observations and showed that the contacts between fluorite and calcite are prevailingly smooth and straight and are clearly crystal faces, many of which are rhombohedral faces of calcite exactly paralleling the calcite cleavage. A few contacts are smoothly rounding. In one specimen the calcite crystals appear much like phenocrysts in a fluorite matrix. When the contacts were more clearly exposed by dissolving the calcite in dilute hydrochloric acid, it was seen that some of them clearly represent crystal faces of calcite and others are equally clearly crystal faces of fluorite. Some few contacts are curving. No ragged contacts or penetration of the calcite by fluorite along cleavage planes were noted.

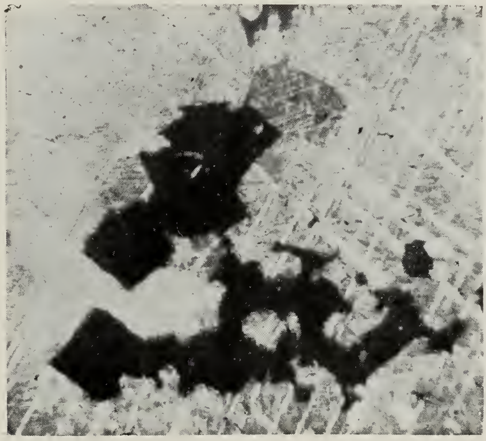

FIG. 24. Fluorite (black) replacing calcite. The fluorite is partly idiomorphic, and in several places its prominent directions are roughly conformable with the twinning striations of the host mineral, (X 50.) (After Currier, L. W., Illinois State Geol. Survey Bull. 41, Pl. II-F, 1920.)

A similar specimen from between the 412- and 500-foot levels of the Daisy mine was also treated with dilute hydrochloric acid to dissolve the calcite, which revealed that some of the contacts between calcite and fluorite are straight faces of relatively large crystals of calcite and elsewhere they are faces of relatively small cubical crystals of fluorite. These relations may be interpreted as contemporaneous intergrowths of fluorite and calcite but do not exclude the possibility of some replacement of calcite by small cubical crystals of fluorite, the latter process being strongly indicated in certain occurrences (Fig. 24). However, there is no evidence that fluorite penetrated along calcite cleavage planes as might be expected if the fluorite were mainly a replacement of calcite.

The relation of calcite and fluorite in a particularly fine-grained intergrowth forming an irregular mass in the central portion of the Hillside vein in the Hillside mine and grading into the more usual coarse vein material was studied under a compound microscope (Fig. 25). The calcite exhibits its own characteristic crystal faces against fluorite, clearly indicating that fluorite has not replaced calcite but that the calcite crystallized first and fluorite then formed around it.

Fig. 25. Photomicrograph of fine inter-growth of calcite (dark) and fluorite (light) from the Hillside vein. Note the crystal outlines of the calcite, which show that it had not been replaced by fluorite.

In conclusion, the somewhat conflicting relationships that have been described may be summarized and interpreted:

1. Some relations (Figs. 23 and 25) show clearly that much fluorite either crystallized contemporaneously with calcite or formed only slightly later, as it incloses but does not replace the calcite.

2. Other relations (Figs. 19 to 22) show clearly that much fluorite is somewhat younger than much of the calcite, as veinlets of it traverse calcite and some inclose angular fragments of calcite. These veinlets have one character usually found in replacement veins—namely, that in many places opposite walls do not "match;" but on the other hand they often inclose angular fragments of calcite that have clearly been broken from the bordering wall and have not been corroded. Furthermore, calcite with its own characteristic crystal faces projects into the fluorite along the walls of many of the fluorite veinlets. In these cases it is evident that calcite has not been replaced

by fluorite, because its crystal outlines have not been impaired. In general, it appears that in the early stages of vein formation calcite was deposited more abundantly than but not entirely exclusive of fluorite; then the vein material was ruptured, possibly by the pressure of the inpushing mineralizing solutions, so that crystals of calcite continued to grow on the walls of the ruptures while solutions were pushing them apart and in the ruptures fluorite was deposited.

3. There was also probably some replacement of calcite by fluorite in the later stages of vein formation (Fig. 24). In the writer's opinion such replacements were minor phenomena, and there is little in the vein structures to indicate a wholesale replacement of vein calcite by fluorite.

OIL AND BITUMEN IN THE VEINS

Petroleum occurs occasionally in openings in the fluorspar veins near Rosiclare. An irregular dark stain near the center of the Daisy (Fig. 3, p. 14) vein is due to oil that seeped out from a relatively open part of the vein and coated and discolored the vein minerals. The oil is light brown, viscous and sticky, and burns readily with a luminous, smoky flame, some of it was sufficiently fluid to drip from the roof of the drift. It dissolves in gasoline, coloring the gasoline a deep yellow, and the residue after the evaporation of the gasoline is distinctly greasy.

According to a former superintendent of the Extension mine, as much as a barrel of oil, honey-like in color and consistency and possessing a distinct petroleum odor came from one vug in the Fairview-Rosiclare vein.

Colorless fluorite in an ore specimen from the Hillside mine (precise place uncertain) contained small cavities up to 0.5 millimeter across, some spherical, others very irregular, all filled with a brown oil, and most of them also included a gas bubble. The surfaces of the cubical fluorite crystals are coated with a thin layer of bitumen, dark brown to black in color, which in the blowpipe flame first glows and then burns off completely. Scalenohedral crystals of calcite occur at some places on this bituminous coating and small crystals of pyrite were later deposited on both the bitumen and the calcite. The apparent sequence of deposition may be represented diagrammatically (A, Fig. 26).

In specimens from the dump of the Hillside mine, in which calcite and fluorite are associated, thin coatings of black bituminous material commonly occur on the minerals in small vugs. Where they are very thin, the bituminous coatings are a dirty yellowish-brown by transmitted light. The bitumen is brittle and has vitreous lustre and conchoidal fracture. Some surfaces of it are minutely mammillary and some show shrinkage cracks. When heated in a closed tube it intumesces and yields volatile products that condense as a brown liquid on the cool sides of the tube. When heated in the blowpipe flame it burns completely without appreciable residue. Surprisingly it does not dissolve appreciably in gasoline, in which respect it behaves similarly to several specimens of petroleum coke that were tested.

In general, these relations indicate that petroleum was present in a few places in a few of the fluorite veins before the crystallization of fluorite ceased. They further indicate that the petroleum evaporated from some of the vugs, leaving only a bituminous residue. The deposition of calcite and then of pyrite on the bitumen in vugs represents a final episode perhaps unconnected with the fluorspar mineralization. The fact that oil is not present in all veins or in all parts of the same vein suggests that it was derived locally from some of the sediments traversed by the mineralizing solutions.

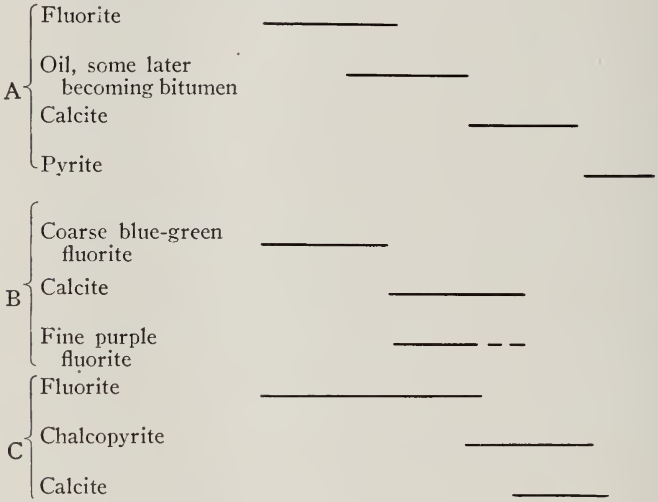

FIG. 26. Diagrams representing the sequences of mineral deposition in specimens from the Hillside vein.

VUGS

Vugs or cavities formed when the veins were deposited are only moderately numerous. The largest ones noted were two by three feet and three by five feet (Hillside mine, 350-foot level south, Pl. IV). They were in calcitic portions of the vein and were lined solely with scalenohedral crystals of calcite. Vugs in highly fluoritic portions of the vein are smaller and are commonly lined with crystals of fluorite. The most beautiful crystals of fluorite, usually blue-green in color, have been found in vugs. The choicest crystals of transparent fluorite are said to be pendant from the roofs of the vugs.

Many specimens from the vugs were studied in detail because of the variety and interesting relationships of minerals in them.

DIRECTIONAL DEPOSITION IN VUGS

A feature of unusual interest is that the deposition of several of the minerals latest to form in vugs was influenced by gravity. The minerals were deposited sparsely on the steep sides and under surfaces of crystals but abundantly on the gently inclined, upper surfaces of crystals. The phenomenon may be called a "snow on the roof" effect, as it simulates the heaping of snow on the roof and not on the walls and under the eaves of a house. These relations imply that the latest vug minerals crystallized out of solutions which filled the vugs and that the crystals settled under gravitative attraction.

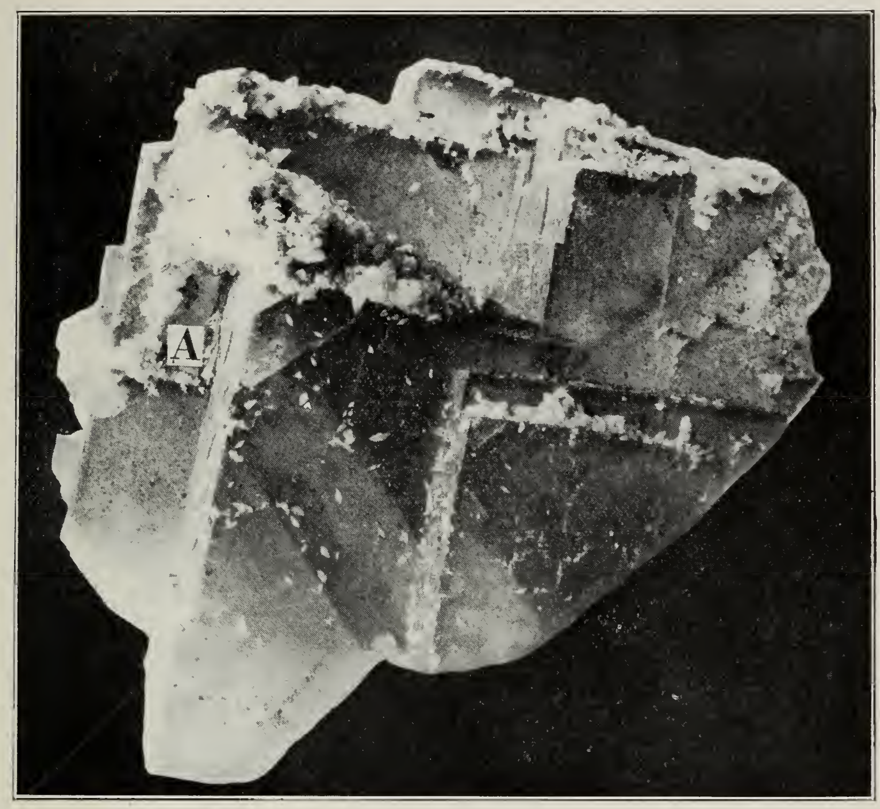

Fig. 27. Pale blue-green crystalline fluorite coated abundantly with scalenohedral crystals of calcite on the flat-lying faces, whereas on the steep faces only scattered calcite crystals occur. At A, a tapering pendant of calcite crystals extends from a higher flat face to a lower one. Specimen is about 4 inches in diameter and was collected from a vug in the Hillside vein.

On the gently inclined faces of pale blue-green fluorite in a specimen in the collections at the Hillside mine, scalenohedral crystals of calcite are heaped like snow on a roof, whereas on the steep faces there are only scattered calcite crystals (Fig. 27). An interesting minor feature is the occurrence of a short "stalactite" or tapering pendant of calcite crystals (A in Fig. 27) descending from a higher flat face to a lower one. Intercrystallized with the calcite are small crystals of purple fluorite, clearly deposited at the same time as the calcite was and therefore of a second generation. The mutual age relations may be represented diagrammatically as in B, figure 26.

In another specimen the scalenohedral calcite crystals coating the fluorite are an inch long but ordinarily their length is less than one-fourth inch. These relations are not exceptional but occur in many specimens in the collections at the Hillside mine or collected underground by the writer.

Less commonly barite is associated with calcite in similar relations. In two specimens in the collections at the Hillside mine some of the originally nearly horizontal faces of cubical crystals of white fluorite have been coated with rosettes of barite blades intergrown with a few scalenohedral crystals of calcite. The calcite and barite are never inclosed, even partially, by the fluorite.

In many specimens chalcopyrite was deposited more abundantly on flat-lying faces of fluorite than on steep faces. At some places the chalcopyrite crystals are partly or wholly embedded in fluorite. In a specimen from a vug in the Hillside vein the relatively flat-lying faces of pale purplish fluorite were coated abundantly with chalcopyrite and calcite whereas steeply inclined faces carry little chalcopyrite and no calcite. Some of the chalcopyrite crystals are indented in the surfaces of the fluorite faces, whereas the calcite crystals are not. In another specimen from the same mine, one set of cube faces of blue-green fluorite carries only a few scattered crystals of chalcopyrite whereas another set of cube faces is abundantly coated with crystals of chalcopyrite and calcite. Some of the chalcopyrite is wholly and some is partially embedded in the outer portions of the fluorite crystals, whereas the calcite is not embedded in the fluorite. The partial embedding of the chalcopyrite shows the apparent order of deposition which may be diagramatically represented as in C, figure 26.

Deposition of pyrite on flat surfaces in preference to steep surfaces of white fluorite was noted in vugs in the Hillside vein. In some instances the pyrite crystals are wholly or partly embedded in the fluorite; in other cases they are not embedded and can be cleanly stripped from the fluorite surfaces. In the Daisy vein a vug lined with fluorite crystals showed the upper surfaces of the fluorite heavily coated with pyrite, whereas the steeply inclined or under surfaces carried little or no pyrite. Directional deposition of pyrite on calcite also was noted in the Hillside mine. Scalenohedral crystals of calcite contained some small crystals of pyrite wholly inclosed but were also coated with similar pyrite crystals. Viewed from one direction no surface pyrite was visible; viewed from the opposite direction it was abundant. In some specimens a later generation of calcite coats the pyrite.

TWO GENERATIONS OF FLUORITE

Small amounts of fluorite are clearly somewhat younger than the main fluorite deposition. Quantitatively this younger fluorite is insignificant but it is of scientific interest.

In a specimen in the Rosiclare mine collections coarse crystals of purple fluorite up to one and one-half inches across are coated with small crystals of purple fluorite up to an eighth of an inch across and intergrown with small crystals of chalcopyrite. Some but not all of the small fluorite crystals are parallel crystallographically with the larger ones but the small crystals of fluorite and of chalcopyrite can be cleanly stripped off of the larger fluorite crystals. Some small scalenohedral crystals of calcite coat the younger fluorite. The sequence of mineral deposition as interpreted may be diagrammatically represented as in A, figure 28.

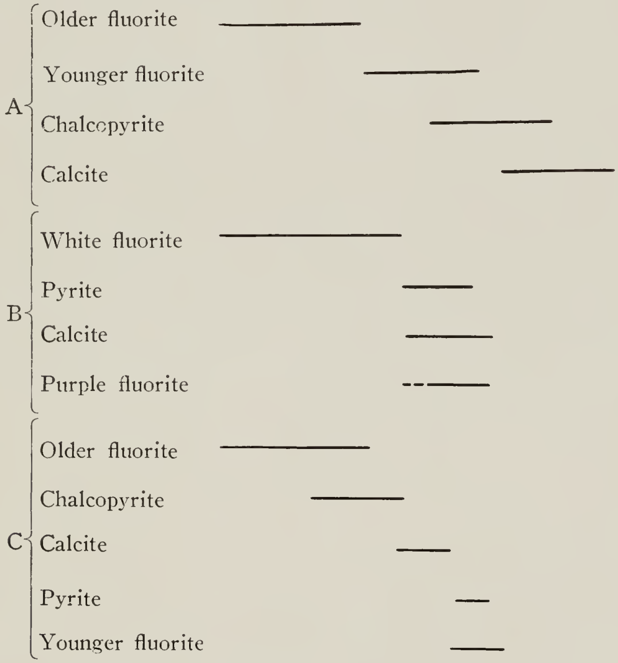

Fig. 28. Diagram representing the sequences of mineral deposition in specimens from Rosiclare and Hillside veins.

In a specimen from the Hillside mine some of the faces of cubical crystals of white fluorite are coated with white calcite crystals with which are intergrown small crystals of pyrite and a few small crystals of purple fluorite.

The apparent sequence of deposition may be diagrammatically represented as in B, figure 28.

In another specimen from the Hillside mine, small crystals of chalcopyrite are enclosed within or indent or coat the faces of cubical crystals of clear, transparent fluorite. A one-eighth inch layer of calcite crystals, on but not in which minute crystals of pyrite occur, coats the fluorite and chalcopyrite. A few small crystals of a second generation of fluorite enclose some of the pyrite. The apparent sequence of mineral deposition may be diagrammatically represented as in C, figure 28.

PURPLE COLORATION OF FLUORITE AROUND PYRITE AND CHALCOPYRITE CRYSTALS

In a number of specimens from the Hillside mine the purple color of some of the fluorite appears to be in some way dependent upon its contact with crystals of pyrite and chalcopyrite. In numerous specimens from vugs in the vein small crystals of pyrite or of chalcopyrite are deposited on the faces, partly indented in the faces or completely enclosed within crystals of white to pale blue-green fluorite. In many of these specimens there is a halo of purple color in the fluorite around exposed pyrite or chalcopyrite crystals but not around the pyrite crystals that are wholly enclosed by fluorite. Furthermore, in the fluorite no purple halos are developed where the pyrite or chalcopyrite is protected by a coating of calcite. Therefore, it may be inferred that mere contact of fluorite with pyrite or chalcopyrite is not sufficient to produce the purple coloration, but that exposure to the air or to liquids in the vugs was also necessary. The presence of the purple coloration around both pyrite and chalcopyrite, sometimes in the same specimen, suggest that iron rather than copper is responsible for the color change.

However, it must also be noted that in other specimens of fluorite coated with crystals of chalcopyrite or pyrite no purple halos are developed around the sulfides.

SOLUTION CAVITIES AND "MUD RUNS"

Some solution of calcite by ground water in veins mainly calcitic is to be expected and should be most extensive near the surface. Surface workings in the vein are now mainly inaccessible and in lower workings solution of vein material is not common but is confined to a few places. It manifests itself in the formation of sinuous, irregular channel-like cavities within the vein. Between the 412- and 500-foot levels in the Daisy mine there was a channel large enough for a man to crawl into. In the roof of the 500-foot level a small solution channel of nearly circular cross-section could be traced with the eye for at least five feet into the roof; it had clearly started along a fracture traversing the calcitic vein material. An open water-course, at some places ten feet wide, follows the vein of the Hillside mine on the 350-foot level and about nine hundred feet north of the shaft.

When first encountered in mining, many of these solution channels are filled with a wet, extremely fine, very plastic, ocherous yellow clay. They are termed "mud runs" by the miners because much of the clay runs out when they are tapped. When the walls are washed clean the cavities exhibit the pitted and etched appearance typical of solvent action. Fluorite intergrown with the calcite appears to have been little if at all dissolved. It is likely that some if not most of the channels connect with solution channels so common in the adjacent limestones. The yellow clay probably represents the residuum from dissolved impure limestone and was washed down into parts of the channels that lie within the vein.

CHAPTER III—BLANKET DEPOSITS

General Statement

Exploitation of the blanket deposits is one of the later developments in fluorspar mining in the Kentucky-Illinois district. With the increasing difficulties encountered in working the vein deposits, owing to exhaustion and to flooding, attention may well be directed toward a more thorough exploration of the blanket deposits. This is especially true as they have the natural advantage of being flat-lying, so that they can be worked from open-pit or shallow underground workings with simple mining methods and with natural drainage for the mines. Preparation for the market is relatively simple, for in contrast to the vein deposits the blanket deposits contain little calcite and galena and do not require jigging and table treatment, nor need very much waste be mined in stoping. Over a period of two and a half years in the recent operation of the Spar Mountain replacement deposits the shipped product constituted 91.7 per cent of the crude mine production. It may be conservatively stated that the final product constitutes 85 to 90 per cent of the crude ore of the blanket deposits as contrasted with 40 to 60 per cent of the vein deposits.

Distribution

The principal blanket deposits of fluorspar are located at Lead Hill and Spar Mountain, about four miles northwest of Cave in Rock. They are nearly horizontal deposits of large lateral but small vertical extent. A small prospect (Renfrew Prospect, Pl. I), also belongs to this class. In 1926, mining activity was restricted to Spar Mountain and the workings there offered the best opportunities for study.

Some of the best territory for blanket deposits lies immediately north of the Spar Mountain mines, in land owned by Mr. Martin Schwerin. Under much of this land the fluorite-bearing horizon lies at depths of 80 to 100 feet below the surface, so that churn-drill methods of prospecting are especially practicable.

Mining Methods

Where the blanket deposits near Cave in Rock are close to the surface they are worked by open-pit methods, but underground methods predominate. The methods of mining closely resemble those used in working the "sheet ground" of the Joplin, Missouri, zinc district. Drifts starting from hillside outcrops follow the deposit into the hill. From the drifts the deposit is stoped out in galleries fifty to one hundred fifty feet wide and three hundred to six hundred feet long, pillars being left at irregular intervals (Pl. VII).

OCCURRENCE

TWO TYPES OF ORE

Banded ore occurs at many places immediately below the Rosiclare shale which marks the upper limit of mineralization, but in the richer and thicker parts of the ore bodies coarse grained ore in masses a few inches to two feet across lies just beneath the shale and is succeeded below by banded ore. The following succession is a fairly typical exposure in the Cleveland workings (Pls. I and VII):

	Thickness	
	Feet	*Inches*
1. Shale, split and ruptured to form sharply outlined, angular slivers which clearly have undergone no replacement; traversed by horizontal sharp-walled veins of fluorite up to eight inches wide, in the central parts of the wider portions of which are vugs	2	
2. Fluorite ore, banded; bands average 1½ to 2 inches thick	2	6
3. Limestone, fine grained		8
4. Fluorite ore, banded; bands inclined at angle of 40° from bedding of overlying limestone; base not exposed	1½+	

The following stratigraphic succession occurs at one place in the Green mine (Pls. I and VII):

	Thickness
	Inches
Shale	8
Ore, finely banded	14
Limestone, with occasional veinlets and replacements of fluorite	24
Ore, banded, bands wider than in higher zones	18
Limestone	..

The two types of ore grade into each other laterally. The wider and richer portions of the ore bodies typified by the first example pinch out laterally from wide masses of pure fluorite into masses of banded ore and these in turn thin and finally yield to limestone as the borders of the ore bodies are reached.

VUGS

Vugs are common in the coarse ores just below the shale cap, and some are lined with exceptionally fine crystals of fluorite and other minerals. They may attain considerable size, and most of them are largest in horizontal dimensions. One vug six inches high was four feet across; another two feet high was five feet across. The widest mass of essentially pure fluorite that was seen occurred in the Cleveland workings and measured four feet across.

INFLUENCE OF STRUCTURE

The fluorite veins in the vicinity of Rosiclare are associated with fissuring and brecciation of the country rocks. Some of the fissuring and brecciation preceded mineralization and furnished channels for the circulation of mineralizing solutions, and some occurred later and fractured the fluorspar veins. In the Lead Hill and Spar Mountain blanket deposits the mineralization in general followed the bedding of the Mississippian strata which in this region are flat lying or only slightly tilted, and have been only slightly fractured with relatively little displacement of the formations.

The blanket deposits lie just east of the area of pronounced faulting[1]. The fracturing of the rocks which has taken place created a few minor faults, but the structure of the formations in eastern Hardin County is controlled by gentle arching and not by faulting[2]. At Lead Hill a few small veins of fluorspar were noted, but blanket replacement deposits were dominant; at Spar Mountain veins were essentially absent. Although brecciation of the roof shale was noted at several localities, it is not widespread and does not imply any considerable movement along the contact either before or during mineralization.

In the Cleveland workings and in the Lead Hill mines, (Pls. I and VII) the fractures are nearly vertical and there has been little or no displacement of the beds along them. In the shale roof they show up clearly as a single fluorite vein one-eighth to one-half of an inch wide or as several nearly parallel closely spaced veinlets. In ore pillars the veinlets in the shale roof continue downward into the banded ore (Fig. 29). The fractures are roughly parallel to the long axis of the ore body, so that in mining operations they have been found to be useful "leaders" in following the ore, as near them the ore is likely to be unusually thick and high grade. It is evident that circulation of the mineralizing solutions was especially active along these fractures, small as they are, and near them the replacement of the limestone reached a maximum.

INFLUENCE OF STRATIGRAPHY

The blanket deposits of fluorite occur in limestones and are notably absent from the associated sandstones and shale except where small fractures

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[1] Weller, Stuart, and associates, Geology of Hardin County: Ill. State Geol. Survey Bull. 41, Pl. I, 1920.

[2] Idem.

in the latter have been filled by fluorite. The base of the Rosiclare sandstone and shale marks the upper limit of notable mineralization in the Lead Hill and Spar Mountain region. The siliceous composition of the sandstone makes it resistant to replacement. The siliceous and aluminous composition of the shale makes it resistant to replacement, and the fineness of grain makes it relatively impermeable to mineralizing solutions. Fluorite and associated minerals occurring in the sandstone and shale are therefore not replacements but fracture fillings.

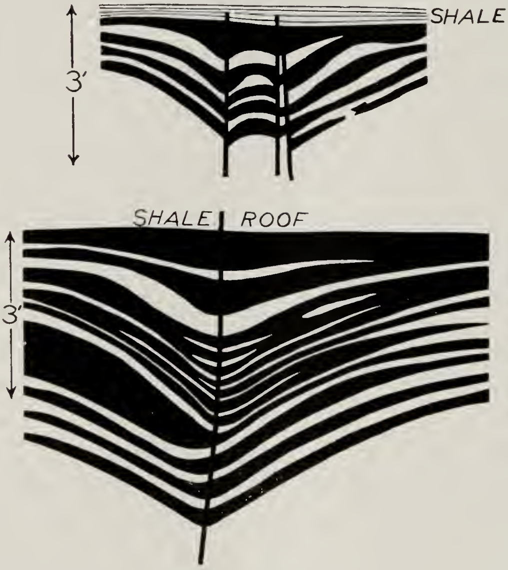

Fig. 29. V-shaped diffusion banding in fluoritic material along small, nearly vertical fractures. Sketched from exposures in the Lead and Cleveland Mines, Spar Mountain.

INFLUENCE OF TEXTURE OF THE COUNTRY ROCK

The blanket deposits are associated principally with the coarser limestones, commonly oolitic in texture. In the Spar Mountain mines the fluorite mineralization appears to have preferred light gray moderately coarse, oolitic phases of the Fredonia limestone, which lies below the Rosiclare formation. The oolite grains are commonly spherical and range from one-half to one millimeter in diameter, but a few are ovoid or pear-shaped, the length of some of them being five or six times the width. The cores of the oolite grains are usually clear calcite which shows distinct cleavage under the microscope; their periphery is finely crystalline calcite. The matrix in which the oolite grains lie is mostly crystalline calcite; structures indicative of minute organisms are rarely seen. Darker gray, denser, non-oolitic or only sparsely oolitic phases of the limestone appear to have been less susceptible to mineralization but are occasionally mineralized.

Although the oolitic phases of the limestone seem to have favored replacement, much unreplaced oolitic limestone remains even in the more productive workings. At one place in the Cleveland mine five feet of apparently unaltered oolitic limestone exists below a 2-foot zone of banded ore. In one drift into the west border of the Cleveland ore body oolitic limestone identical in appearance with that under thick ore exists where there is absolutely no mineralization. In another drift the ore thins as the oolitic limestone thins and its place is taken by dense, non-oolitic limestone.

EXTENT OF MINERALIZATION

Although the maximum mineralization occurs nearest the shale parting between the Rosiclare sandstone and the Fredonia limestone, which shale marks its upper limit, it may extend with interruptions as far as 30 feet below the shale parting. For example, in the Cleveland open-pit, banded ore not only immediately underlies Rosiclare sandstone and its shale but also occurs twenty feet below the shale, under a bed of fine-grained, non-oolitic limestone. At one place in the Cleveland workings three distinct zones of banded ore are separated by beds of dense, non-oolitic limestone.

Origin

The vein deposits have been interpreted as formed mainly by the replacement of the brecciated materials of fault zones and by some filling of open spaces. In the formation of the blanket deposits the mineralizing solutions were guided by a few small fractures and by bedding-planes—particularly the one under the relatively impervious bed of Rosiclare shale.

Characteristic features of the blanket deposits include (1) the absence of fracturing on a large scale, (2) the preservation of features characteristic of the limestone, (3) the prevailing absence of important mineralization in sandstones and shales and its presence in more soluble limestone, (4) the obvious influence of narrow fractures on the form and distribution of wide ore bodies, and (5) the common development of a peculiar type of banded ore which implies rhythmic deposition during replacement by diffusion of the mineralizing solutions through a solid rock medium.

The preservation in the ore of structures characteristic of the rock in which the ore occurs is one of the best evidences of replacement. Structures originally in the limestones and preserved in the fluorite ores include fossils, stylolitic structure, oolitic structure, and the forms of calcite crystals. At Lead Hill a crinoid stem was clearly recognizable although partly converted into fluorite. Numerous well preserved fossil echinoderms (blastoids), some of which have been replaced by both quartz and fluorite, are found in the soils derived from banded fluorite ore and limestone at the Hamp mines (Pl. I) near Karbers Ridge and at the Renfrew Prospect (Pl. I). Some of the delicate ambulacral plates are now wholly fluorite. Fluorite may also fill or inclose, silicified bastoids.

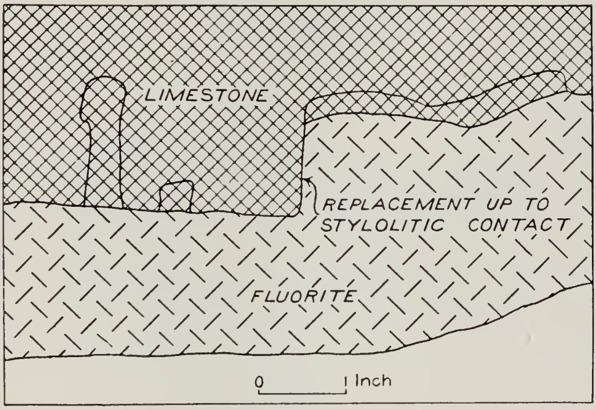

Fig. 30. Sketch showing stylolitic structure forming boundary between limestone and fluorite in C. M. Miller Mine, Lead Hill. The fluorite has developed by selective replacement of the limestone below the stylolitic parting.

At some places in the C. M. Miller mine (Pl. I) at Lead Hill the boundary between fluorite ore and limestone is a stylolitic parting (Fig. 30) which indicates that the fluorite replaced the lower of two limestone beds.

Microscopic stylolitic structure has been reported in ores mainly fluorite from Lead Hill [3] and is evidently an inheritance from the limestone that the ore replaced. Similar structures were observed in banded fluorite ore from the Cleveland mine (Pls. I and VII) at Spar Mountain (Fig. 31).

In a specimen from the Cave in Rock mine (Pl. I) in which oolitic limestone grades into fluorite ore, the oolitic texture was easily recognizable in the ore although the oolite grains had been converted into fluorite.

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[3] Bain, H. Foster, Fluorspar deposits of southern Illinois: U. S. Geol. Survey Bull. 225, 1905.

Fig. 31. Stylolitic partings on a microscopic scale preserved in banded material now almost wholly fluorite. Cleveland Mine, Spar Mountain. The field shown is about one centimeter across.

The outlines of microscopic calcite grains are preserved in ore now mainly fluorite at Lead Hill (Figs. 32, 33).

If the fluorite bodies be fillings of flat-lying fractures there is no apparent reason for their restriction to certain kinds of rocks. On the other hand, limestones are well known to be susceptible to replacement whereas sandstones and shales are commonly resistant to replacement, so that the restriction of fluorite ore to limestone country rock is suggestive of replacement of the limestone by fluorite.

The peculiar banded structure shown in the fluorite of Lead Hill and Spar Mountain can have been produced apparently only by replacement. Some of the best exposures of the banded ores occur near the portal of the main or lower tunnel of the Cave in Rock mine (Pl. I and fig. 46), where the mineralized zone is at least eight feet thick and in general parallels the bedding of the associated sandstone, shale, and limestone. The ore consists of bands of coarse fluorite up to one and a half feet wide alternating with ore that is finely banded (figs. 34 and 35). At one place 74 bands were counted in a width of 3½ feet.

Fig. 32. Photomicrograph (polarized light) of banded fluorite material from Lead Till. The black areas are fluorite and the light areas mainly calcite. (After Bain, H. Foster, Fluorspar deposits of southern Illinois: U. S. Geological Survey Bull. 225, Pl. VI-B, 1905.)

Fig. 33. Photomicrograph (natural light) of the same field shown in figure 32, showing the outlines of the original calcite grains which are now largely replaced by fluorite. (After Bain, H. Foster, Fluorspar deposits of southern Illinois: U. S. Geological Survey Bull. 255, Pl. VI-A, 1905.)

As a rule the banding is nearly parallel to the bedding planes of the inclosing rocks, but there are marked departures from parallelism (Fig. 34). In a few places in the Spar Mountain workings the banding is V- or W-shaped in cross-section (Fig. 29), where it follows narrow fractures that continue in the shale and sandstone roof.

FIG. 34. Diffusion banding in fluorspar at Cave in Rock mine, Spar Mountain; 74 bands were counted in a width of 3½ feet. The bedding is marked by a horizontal band of shale at A. The diffusion bands make an angle of approximately 30° with the bedding.

Despite the prevailing parallelism between the banding and the bedding, the occasional divergences cited above demonstrate that the banding is not an inheritance from either bedding or cross-bedding of the sediments in which the ore occurs, but is clearly controlled at places by small fractures cutting across the bedding-planes.

Banding of this sort is not confined to fluorite deposits but has been observed in many metalliferous deposits. Although it is not common, a number of examples have been described in the literature of ore deposits and it is now generally understood to be the result of rhythmic precipitation during the replacement of a rock, commonly limestone, through the agency of diffusing mineralizing solutions. The mechanism of the process has been

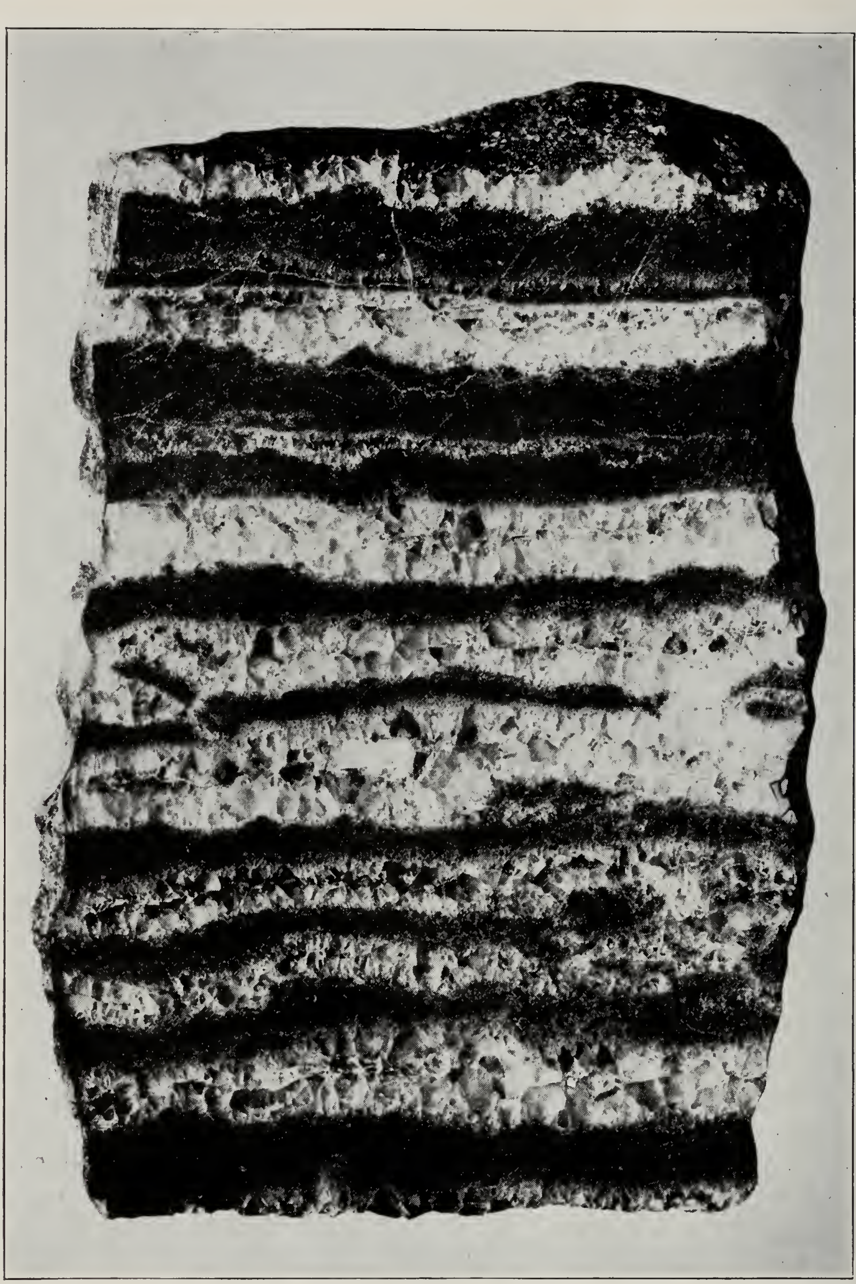

FIG. 35. Diffusion banding in fluoritic material from Lead Hill. The individual bands of coarse fluorite (white in the photograph) are ½ to ¾ inch wide. (After Bain, H. Foster, Fluorspar deposits of southern Illinois: U. S. Geological Survey Bull. 255, Pl. V, 1905.)

summarized[4] and some particularly good examples in the zinc ores of Leadville have been recently described and figured.[5] In the blanket deposits of fluorspar ores the mineralizing solutions entered along a plane between limestone and shale, and diffused downward into limestone from the relatively impervious shale, penetrating most deeply along cross-fractures and replacing the limestone rhythmically with fluorite.

In diffusion banding produced in laboratory experiments the bands usually, but not always, become wider spaced farther from the source of the solutions,[6] but in the replacement banding in ore deposits there seems to be more uniform spacing, which indicates some unknown modifying factors. In the banded fluorspar ores in the blanket deposits, an increase in spacing downward from the shale cap was noted at a few places. In one exposure of three feet of banded ore the bands at the top, next the shale roof, are one-half inch wide, and those at the bottom are one inch wide.

MINERALOGY OF THE BLANKET DEPOSITS

GENERAL

In the blanket deposits, the layers in the banded material are of two sorts. Coarse grained bands one fourth to three fourths of an inch wide are composed wholly of colorless to gray to purplish fluorite in crystals that may reach half an inch across. At some places small cavities which occur in the centers of the bands are lined with small fluorite crystals and contain some colorless to smoky quartz. Alternating with the coarser bands are fine grained bands one half to three fourths of an inch wide which are composed mainly of gray to pale purplish fluorite with minor amounts of finely crystalline quartz.

Grab samples were analyzed with the following results:

Analyses of composite grab samples of banded fluorite ores from Spar Mountain[a]

	Lead Mine Spar Mountain	Cleveland Mine Spar Mountain
	Per cent	*Per cent*
Silicon dioxide—SiO_2	4.12	3.05
Fluorine—F	44.65	45.65
Calcium—Ca	48.37	49.05
Carbon trioxide—CO_3	1.93	1.37
Aluminum oxide—Al_2O_3 (by difference)	.52	.22
Ferric oxide—Fe_2O_3	.41	.66
Totals	100.00	100.00

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[a] Lindren, J. M., analyst.

[4] Stansfield, J., Retarded diffusion and rhythmic precipitation: Amer. Jour. Sci., 4th Ser. Vol. XL III, pp. 1-26, 1917.

[5] Emmons, S. F., Irving, J. D., and Loughlin, G. F., Geology and ore deposits of the Leadville mining District, Colorado: U. S. Geological Survey, Prof. Paper 148, pp. 202-204 and Pl. 60, 1927.

[6] Stansfield, J., Op. cit., pp. 23-25.

From these determinations the components may be recalculated as follows:

	Lead Mine Spar Mountain *Per cent*	Cleveland Mine Spar Mountain *Per cent*
Silicon dioxide—SiO_2	4.12	3.05
Calcium carbonate—$CaCO_3$	3.22	2.28
Calcium fluoride—CaF_2	91.73	93.79
Aluminum oxide—Al_2O_3	.52	.22
Ferric oxide—Fe_2O_3	.41	.66
Totals	100.00	100.00

Much of the banded ore is therefore a high grade ore which requires no concentration to prepare it for the market if it be cleanly mined.

It might be expected that replacement would be less and less complete as the mineralizing solutions penetrated farther into the limestone. This is well shown in specimens from the Green mine (Pl. VII). In the upper layer of banded ore just below the shale cap the finer bands are mainly fluorite with which are associated small amounts of quartz and very little calcite; this ore is probably similar in grade to that in the Lead and Cleveland mines. In the lower zone of banded ore the finer bands contain abundant calcite. The difference in calcite content in ores identical in general appearance was recognized in the field by testing with dilute (10 per cent) hydrochloric acid. The fine bands in the upper zone did not effervesce when acid was applied but those of the lower zone effervesced freely.

The minerals of the coarser non-banded ores are the same as those of the vein deposits but their proportions are significantly different. They include the following:

Primary	*Secondary*	*Miscellaneous*
Fluorite	Barite	Petroleum and Bitumen?
Calcite	Fluorite	
Galena	Smithsonite	
Sphalerite		
Quartz		
Chalcopyrite		
Marcasite		

The principal difference in mineral composition between the vein and the blanket deposits is the proportion of calcite; in the veins calcite is the dominant mineral, but in the blanket deposits it is absent from the banded ore except as remnants of limestone and is very subordinate in the coarse non-banded ores.

Of the other minerals barite is of secondary commercial importance. It is saved in mining and shipments are made when considerable amounts have accumulated. Galena has been recovered in the past, but it is very subordinate and no attempt is made to recover it at present. Sphalerite is inconsequential in quantity.

PRIMARY FLUORITE

Fluorite is the dominant mineral of all the blanket deposits. The largest and most perfect crystals are developed in the vugs that usually occur in the coarser ore just below the shale capping. Individual fluorite crystals as large as six inches across were attached to the roof of one vug, but usually they are less than three inches in diameter. Handsome specimens of blue-green fluorite two and one-half by three feet across, made up of cubical crystals one to seven inches across, were seen at the machine shop of the Benzon Company at Cave in Rock.

The fluorite may be colorless or light gray, pale greenish-blue, light amber, pale purple, or deep purple. It varies from transparent to translucent, the petroleum-bearing varieties being especially likely to be clouded and translucent. Small amounts of colorless fluorite clear enough to be suitable for optical uses form the centers of some crystals. The variations in color may be irregular or bands of different color may parallel the cubical crystal faces. For example, in one two and one half inch cube the interior is pale amber, covered successively by a purple layer an eighth of an inch thick and by a pale greenish-blue layer a fourth of an inch thick, both of which parallel the cubical faces.

The cubical faces of some crystals have a dull "frosted" appearance, suggestive of etching. However, small areas of such surfaces slightly depressed below the rest have a brilliant luster, which indicates that the "frosting" is not due to etching but to the deposition of an outer layer of minute crystals of fluorite parallel to the main crystals.

The exposed surfaces of both coarse and fine bands of the fluorite in specimens of banded ore from old dumps at the Cave in Rock mine are deep purple, whereas freshly fractured surfaces are markedly paler purple. This suggests that weathering possibly affects the color of some fluorite.

SECONDARY FLUORITE

Nearly all of the fluorite clearly belongs to a single period of primary mineralization, but during a later period fluorite was deposited at a few places in amounts too small to be commercially important. For example, in ore from near the north end of the Cleveland workings, crystals of pale purple fluorite a fourth of an inch to an inch across are encrusted with a finely crystalline aggregate of calcite and pale purple fluorite with which is associated a little barite; apparently all three of the encrusting minerals were deposited contemporaneously. A finely crystalline aggregate of barite, pale purple fluorite, and calcite has partly replaced large crystals of white calcite that occur in some of the vugs near the north end of the Cleveland workings. The exceedingly irregular contacts between the fine aggregate and the coarse calcite, and remnants of calcite in the fine aggregate having the same crystal orientation as the large calcite crystals, are evidences that the fine aggregate has replaced some of the calcite.

SOLUTION OF PRIMARY FLUORITE

Evidence that some of the primary fluorite was dissolved before secondary calcite and fluorite were deposited was noted at a number of places, especially in the Cleveland workings. When the finely crystalline calcite that coats pale yellow fluorite in the roof of a vug near the north end of these workings was dissolved with dilute hydrochloric acid, the surface of the fluorite was found to be as rough as a piece of coarse sand paper due to the irregular projection of small pinnacles of fluorite without crystalline form. Evidently the fluorite was irregularly dissolved by circulating waters and calcite was later deposited on the ragged solution surface. The surfaces on two sides of another piece of fluorite from the Cleveland workings were raggedly pinnacled and pitted, the pits having concavely rounded surfaces typical of solvent action.

A crystal of fluorite found on the dumps at Spar Mountain presented parts of three cubical faces that were scored and pitted, and the crystal corners and edges were rounded, all of which plainly indicate solvent action.

The replacement of fluorite by bladed crystals of barite (p. 60) is also evidence that some of the fluorite was dissolved.

PRIMARY CALCITE

In general, calcite is comparatively rare in the blanket deposits (p. 56). It occurs as minute grains in the finely banded ores, where it seems not to have been introduced during mineralization but to have been derived from the limestone, so that it is a recrystallized remnant of incomplete replacement. This view of its origin is supported by the fact that the bands farthest from the source of the diffusing solutions generally contain the most calcite.

Coarsely crystalline calcite is abundant at some places in the coarser non-banded ores in which occur numerous vugs. Some single crystals with continuous cleavage faces are six to nine inches across and at some places lie beside large crystals of fluorite, neither mineral coating the other and both together constituting apparently the last primary minerals to crystallize in the vug. At other places calcite occupies the center and fills in between the perfect cubical crystals of fluorite which line the walls of flat vugs. Therefore, calcite crystallization seems to have begun late in the primary mineralization, before crystallization of fluorite had ceased, and persisted after fluorite deposition had ceased. The coarse calcite seems to be more common on the floors than on the roofs of vugs. It has been entirely dissolved from vugs nearest the surface.

SECONDARY CALCITE

In some vugs in the Cleveland mine pale buff calcite in crystals up to one-fourth inch long and possessing scalenohedral and rhombohedral faces coats buff to pale purple fluorite in cubical crystals up to an inch across. In other vugs in the same workings a finely crystalline aggregate of calcite and barite forms a crust as much as one eighth of an inch thick on cubical fluorite crystals up to one inch across.

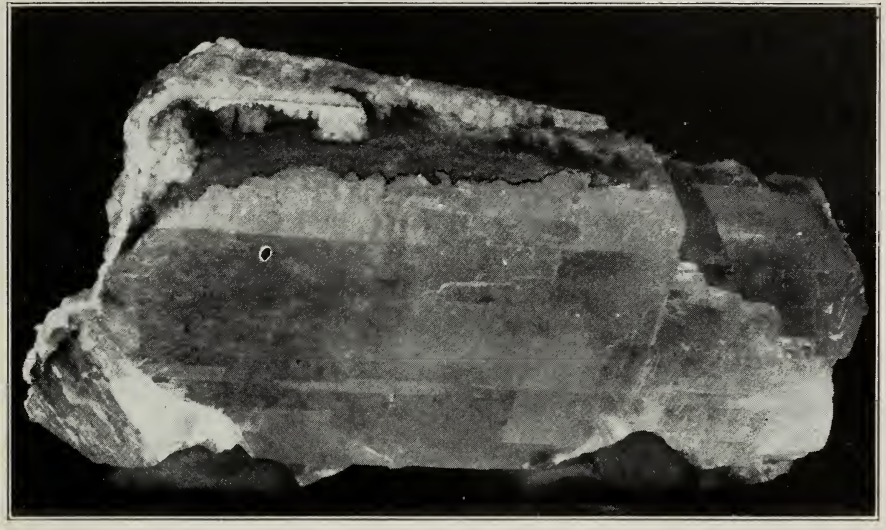

FIG. 36. Calcite crystal with barite coating beneath which solution produced a space in which a second generation of calcite was deposited. Less than half natural size.

The replacement of coarse calcite by fine aggregates of fluorite, barite, and calcite is described on page 58.

SOLUTION OF PRIMARY CALCITE

In certain vugs near the north end of the Cleveland workings calcite crystals five inches or more across were coated with a thin layer of finely crystallized barite. Later some of the calcite beneath this coating was dissolved leaving very rough and irregular surfaces; still later some very finely crystalline calcite was deposited in the spaces so produced (Fig. 36).

BARITE

Barite is significantly absent from most of the fluorite ore in the blanket deposits. It appears to be a secondary mineral formed after—perhaps long after—the deposition of the primary fluorite but contemporaneously with the secondary fluorite (pp. 57-58). It either coats or replaces primary calcite and fluorite or replaces sandy limestone, and is restricted to deposits near the surface.

Its occurrence is best illustrated in the northern part of the Cleveland workings, where, owing to the slope of the hillside, the horizontal drifts approach and finally reach the surface as they are extended northward. As the surface is approached barite begins to appear in vugs in the coarse ore and is most abundant nearest the surface. At some places it forms pendants or blunt stalactites hanging from the fluorite crystals in the roofs of the vugs. Some of the pendants are stained brown superficially by limonite, and on the brown-stained surfaces small tufts of white barite crystals of a second generation have been deposited, showing clearly that barite was deposited not only later than the primary fluorite but also after the deposit had been somewhat oxidized. Not only are barite stalactites or pendants attached here

Fig. 37. Barite replacing limestone along bedding planes. Barite Drift, Spar Mountain. Two-thirds natural size.

and there to fluorite crystals on the roofs of the vugs, but at another place barite completely coats the fluorite crystals on the floor of the vug, showing clearly that it was deposited by waters dripping from the roof of the vug. Generally the barite occurs as a finely crystalline aggregate with or without some secondary fluorite and calcite, but at a few places where the finely crystalline aggregate is in contact with fluorite, an occasional bladed barite crystal as much as three-fourths of an inch long penetrates the fluorite (p. 62). Barite is also found as a replacement of coarse primary calcite in vugs in the Cleveland workings and of vein calcite and sandy limestone in the shallow Barite workings (Pl. VII). At a few places in the Barite workings barite occupies the center of fluorite veinlets that cut across the bedding of the nearly flat strata of sandy limestone, in which case it is probably a replacement of vein calcite. More commonly the barite, in finely granular aggregates, or in aggregates of bladed crystals up to an inch in length, essentially pure or intergrown with fluorite, occurs as irregular bands nearly parallel to the bedding planes of the sandy limestone (Fig. 37). One nearly horizontal mass of barite three feet wide has a ragged sliver of limestone near the middle.

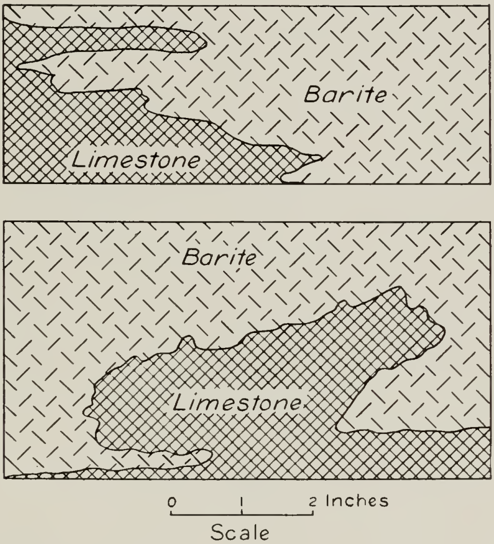

Fig. 38. Sketches showing irregular replacement of limestone by barite at Barite Drift, Spar Mountain.

ORIGIN OF BARITE

Evidence that the barite is a replacement of fluorite, calcite, and limestone near the surface is found in the uneven contact between barite and aggregates of fluorite, calcite, and limestone (Figs. 37 and 38); the change from limestone to barite laterally along the direction of bedding (Fig. 38) ; the abundance of fluorite in unreplaced remnants of sandy limestone and its absence in adjacent barite (Fig. 37) ; the occurrence of bladed barite crystals or their impressions only on the surface of fluorite; and the intergrowth of barite and limonitic pseudomorphs of siderite on fluorite.

In replacement, the replacing mineral may either assume its own characteristic crystal form, as in the case of cubes of pyrite replacing the silicates in a schistose rock; or it may assume the form of the substance replaced, as in the case of pyrite preserving perfectly the form of a fossil shell. Barite tends strongly to assume its own characteristic form of blade-shaped crystals when it replaces other minerals. In several instances well developed cubical crystals of fluorite retained the impressions of bladed crystals of barite, although all the barite had been dissolved. It is noteworthy that all bladed barite and impressions are superficial on the coarsely crystalline fluorite. In no instance were barite blades wholly inclosed by the fluorite, as should be the case at least occasionally if the two minerals were contemporary. Most of the fluorite is sufficiently transparent that barite blades within it could be readily seen if they were present.

In some instances barite is intergrown with limonite pseudomorphic probably after siderite, because in a few cases there are suggestions of rhombohedral form and curved cleavage faces typical of siderite, and there is also some effervescence with concentrated hydrochloric acid which would occur with siderite. The limonite (originally siderite) occurs mainly in the barite and occasionally in contact with the fluorite where it is adjacent to barite; it never occurs with the fluorite if barite is not present. Apparently barite and a little siderite simultaneously replaced fluorite.

QUARTZ

Quartz is rare in the blanket deposits. Minute crystals of quartz coating etched and pitted surfaces of cubical purple fluorite crystals were noted at one place in the Cave in Rock mine. Like barite it probably has no connection with the main fluorite mineralization, but was deposited after the fluorite in vugs had been partially dissolved, probably by the action of waters percolating downward from the surface.

GALENA

Galena is in general rare in the blanket ores, and at present no effort is made to recover it. Crystals up to half an inch across, most of which have ragged outlines although some show smooth cubical faces, were noted especially in the fine grained phases of the ore in the C. M. Miller mine at Lead Hill. A few crystals lie beside fluorite crystals in the vugs in moderately coarse phases of the ore. The largest masses were of fist size in which the galena was intergrown with amber fluorite. It is clearly a primary mineral and appears to have been deposited at the same time as the fluorite with which it is associated.

CHALCOPYRITE

Chalcopyrite occurs as inclusions within cubical crystals of fluorite from the Cleveland workings. The crystals were honey-yellow within and pale blue in the outer one-fourth to one-half inch, the boundaries between the two colors being straight and parallel to the cube faces. The cleavage and the crystal structure were continuous from the yellow to the blue fluorite.

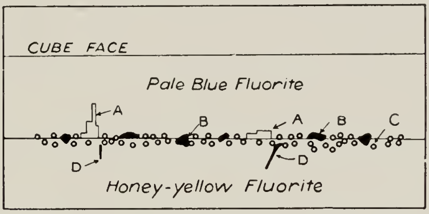

Fig. 39. Sketch showing negative crystal faces of fluorite (A) and inclusions of chalcopyrite (B), petroleum (C), and marcasite (D) along transition plane from yellow to blue fluorite, in crystal from Cleveland workings, Spar Mountain. Magnified about 5 times.

It is clear that there was a notable change in conditions between the deposition of the yellow fluorite and that of the blue fluorite, because the contact between them is marked by negative crystal faces of fluorite, chalcopyrite crystals, and oil inclusions (Fig. 39) and in the outer portions of the yellow fluorite there are a few marcasite crystals.

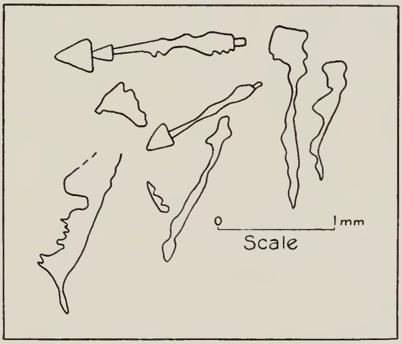

Fig. 40. Sketches showing marcasite inclusions in fluorite. Cleveland workings, Spar Mountain.

MARCASITE

Marcasite inclusions were noted in several specimens of transparent fluorite from the Cleveland workings (Figs. 39 and 40).

OIL AND BITUMEN

Oil inclusions are fairly common in the coarser fluorite ores of Spar Mountain which formed mainly during the late stages of the primary mineralization. They follow crystallographic planes in the fluorite. When freshly broken or when drilled with compressed air drills, much of the ore yields a distinct petroleum odor.

One specimen of a dirty amber fluorite which had a pronounced petroleum odor when it was freshly broken contained minute inclusions, most of them less than 0.01 millimeter in diameter, of yellowish fluid each bearing a gas bubble. It is evident that the dirty appearance of the fluorite is due to the inclusions, which are invisible to the naked eye. In another specimen the diameter of the oil inclusions ranged from 0.015 to 0.075 millimeter. In a specimen of clear and nearly colorless fluorite in Mr. J. W. H. Blee's collection from Spar Mountain, several rounded cavities readily visible to the unaided eye are filled with amber petroleum and a mobile gas bubble. These inclusions are several millimeters across, and the bubble moves like a level bubble when the specimen is shifted about. In a specimen of amber fluorite found by the writer, rounded cavities up to one and a half millimeters across were filled with oil and a gas bubble, or if empty, their walls were partly or wholly coated with a brown to black residuum from the evaporation of the petroleum. In some specimens some bitumen spots occur on the cavity walls even when the cavities are still mainly occupied with oil. In one specimen cubical crystal faces of fluorite are pitted with hemispherical depressions that are clearly the moulds of oil globules; the walls of some of the depressions are coated with bitumen from the evaporation of the petroleum and others are filled with calcite. The presence of bitumen as coatings on fluorite crystals as described below is evidence of still later oil deposition.

Although more noticeable in the coarsely crystalline ore, petroleum is present also in the banded ore. When a sample of banded ore was broken from the Cleveland workings, the odor of petroleum was distinct and the fluorite crystals in small vugs in the coarser bands were thinly coated with bitumen which showed small shrinkage cracks.

Cubical crystals of white fluorite in an elongate vug in banded ore from the Spar Mountain mines are coated with jet black, brittle, and combustible bitumen as much as an eighth to a fourth of an inch thick. Before the blowpipe it burns with a luminous smoky flame with the odor of burning crude oil, but combustion ceases as soon as the blowpipe flame is withdrawn.

In one specimen from Spar Mountain bitumen coatings on cubical crystal faces of fluorite have been encrusted with masses of barite crystals.

Inclusions of a nearly colorless fluid that is probably water occur in some of the same specimens that contain oil inclusions. Like the oil inclusions, the water inclusions follow certain crystallographic planes of the fluorite, and each carries a gas bubble. They vary greatly in outline and some of them are irregularly angular. Their outlines are not prevailingly circular, as are those of the oil inclusions, which indicates that the liquid has a surface tension lower than that of petroleum.

Although oil began to be deposited during the period of fluorspar deposition as shown by the inclusions, its deposition continued after the deposition of primary fluorite ceased, as shown by the coatings on the crystals.

CHAPTER IV—ORIGIN OF THE FLUORSPAR DEPOSITS

From the evidence available in both the Illinois and the Kentucky portions of the fluorspar district it appears that the vein deposits were formed along fault zones, all of which are of the so-called "normal" type. In some instances, as for example in the Lucile mine at Marion, Kentucky, where a vein of nearly pure fluorite up to two feet wide cuts sharply through walls of quartzite with no evidence of replacement, they are relatively simple fractures but most of the faults are zones of intimate brecciation many feet in width, in which it seems beyond question that mineralization was accomplished in part by the filling of open spaces between the breccia fragments (Fig. 14). Veins in which most of the limestone fragments are angular but not ragged probably had such an origin, but in many others in which the limestone fragments enclosed in vein material are extremely ragged (Fig. 5, p. 17) it is obvious that the process of replacement has played an important part. Both sharply angular and ragged limestone fragments may occur as enclosures in calcite and fluorite in the same vein or even in the same hand specimen, due partly to the fact that some limestones are more susceptible to replacement than are others. Sharp and often fairly straight walls of limestone in "frozen" contact with pure vein material are interpreted as marking fractures between fault breccias of limestone and unbrecciated limestone walls. The brecciated material was so readily previous to the mineralizing solutions that it yielded completely to replacement while the unfractured walls in most places were unaffected. Although it is difficult to estimate the relative importance of the processes of fracture filling and of replacement in the vein formation, replacement appears to have been the dominant process.

The presence of fluorspar veinlets traversing vein calcite (Figs. 21 and 22) and of replacement veinlets of galena following the central portions of fluorite veinlets, indicate that some fracturing occurred during the later stages of mineralization. It may have been caused by adjustments between the vein walls in rocks stressed by regional warping, or it was possibly induced by the pressure of the mineralizing solutions, although there is no direct evidence that such was the case.

The fine banding of the blanket deposits of Spar Mountain and the relations of this banding to minor fractures shows that these deposits are products of limestone replacement. No large veins marking the trunk channels along which the replacing solutions ascended have been found, although future exploration may disclose them. The upward movement of the solutions was checked by the shale layer beneath the Rosiclare sandstone, so that they were forced to spread laterally beneath the shale and replaced oolitic limestone for several feet beneath it. The replacement origin of these deposits is in harmony with the evidences of replacement found in the veins.

The replacement of limestone on a scale such as observed in both blanket and vein deposits implies an intimate penetration of the limestone by the mineralizing solutions; this is notably true where stylolitic and oolitic structures have been preserved in minute detail in material now wholly fluorite (Fig. 31, p. 51). Such intimate penetration seems to imply a highly mobile mineralizing solution.

The preservation of single stylolitic partings extending undisturbed through a foot or more of vein calcite and fluorite affords apparently conclusive evidence that replacement was in places the dominant process of mineralization.

The temperature of the mineralizing solutions was probably moderate. No minerals diagnostic of high temperature conditions are present either in the veins or in the blanket deposits. The inclusions of amber-colored liquid petroleum in fluorite during the late stages of primary mineralization indicate that the temperature was probably below three hundred degrees Centigrade.

No new evidence bearing upon the source of the mineralizing solutions was acquired in the course of this investigation. Bain,[7] Fohs,[8] Weller and Currier [9] have all regarded them as emanations from deep lying bodies of molten rock whose presence is indicated by scattered dikes of igneous rock and possibly also by faulting.

Evidence of an igneous source for the mineralization solutions is found in "the presence of basic dikes and sills, and of fragmental acid igneous material which may be explosive products of volcanism. These opposite chemical types of igneous rock in the same province make possible the postulation of magmatic differentiation at depth, and indicate that the region was one of more or less pronounced igneous activity, that is, it overlies a mass of igneous rock of which the dikes, et cetera, are offshoots. The proximity of a large igneous intrusion is also suggested by a slight doming of the strata and the complex pattern of mosaic block faulting."[10]

This opinion of the source of the mineralizing solutions most nearly accords with all the facts now at hand. The nearly quartz-free character of the fluorspar deposits accords well with the opinion that they are related in origin to the quartz-free basic dikes of the region.

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[7] Bain, F. Foster, Fluorspar deposits of Southern Illinois: U. S. Geol. Survey Bull. 255, pp. 61-67, 1905.

[8] Fohs, F. J., Fluorspar deposits in Kentucky: Kentucky Geol. Survey Bull. 9, pp. 61-63. 1907.

[9] Weller, Stuart, and associates, Geology of Hardin County: Illinois State Geol. Survey Bull. 41. 1920.

[10] Currier, L. W., (Part V—Economic Geology) Geology of Hardin County: Illinois State Geol. Survey, Bull. 41, p. 278, 1920.

CHAPTER V—MINE DATA, VEIN DEPOSITS

Rosiclare Vein

(Secs. 8, 5, T. 13 S., R. 8 E., Sec. 32, T. 12 S., R. 8 E.)

The Rosiclare vein, which has yielded most of the Illinois production, extends from beneath Ohio River northward for about two miles (Pl. II).

The strike of the Rosiclare vein varies from nearly north and south near Ohio River to about N. 45° E. near No. 4 shaft and about N. 25° E. near the northern limit of the Rosiclare property. It dips to the west at angles varying from 70° to nearly 90°. It has been mined beneath the river for about 800 feet but has not been identified south of the river in Kentucky, although several small veins, some of which have been worked, occur nearly in line with it.

It is controlled by two companies. the Franklin Fluorspar Company which has developed the southern part of the vein, and the Rosiclare Lead and Fluorspar Mining Company which has developed the northern part. Named in order from Ohio River northward the principal shafts in the vein are the Extension, the Annex, the Good Hope, the New, and the No. 4 shafts on the Franklin properties, and the Rosiclare, the Rosiclare Plant, and the Rosiclare Air shafts on the Rosiclare properties (See Pls. I, II, and III and Fig. 41).

Fig. 41. Main shaft and mill of Rosiclare Lead and Fluorspar Mining Company.

In January, 1924, production from the vein ceased on account of the flooding of the Rosiclare mine, (p. 11). It was therefore impossible to study the vein underground but much information concerning it was obtained from the records of the two controlling companies and from a study of mine dumps and of cabinet specimens. R. C. Allen's report on the Rosiclare mine was particularly valuable for the information it contained.

VEIN WIDTHS

The maximum widths, twenty-five to thirty feet, were found in the northern or main Rosiclare ore body developed by the New, the No. 4, the Rosiclare Main, the Rosiclare Plant, and the Roscilare Air shafts, but the average width in this ore body probably did not exceed seven feet. In the Good Hope ore body the ore in various blocks averaged four to twelve feet wide. Still farther south, in the Extension and Annex workings, the average width was about seven to eight feet and the maximum width (near the surface) was twenty feet. On the 200-foot level about 1900 feet south of the Extension shaft the vein carried three and a half feet of fluorspar.

The vein was comparatively narrow near Ohio River, then widened to form the ore-body developed by the Extension and Annex shafts, north of which it pinched for about four hundred feet then widened to form the Good Hope ore body, north of which it again pinched for five hundred to one thousand feet, then widened to form the great Rosiclare ore-body developed continuously for about 5,900 feet, beyond which the northernmost Rosiclare workings showed that the vein was again pinching, as for example the last one hundred fifty feet on the 420-foot level which showed lean ore ranging up to four feet wide.

BEHAVIOR IN DEPTH

According to mining experience, the vein pinches at moderate depths, where it becomes almost wholly calcite. In the Extension workings it becomes calcitic at about the 300-foot level; in the Good Hope mine, workable ore extended to the 400- or 475-foot levels below which calcite dominated: farther north, in the great Rosiclare ore body, the ore extended deeper but showed signs of pinching with depth, as on the 620-foot level widths of three to four feet were most common and in the deepest level—the 720-foot level of the Plant shaft—very little ore was found. However, the drift on this level was only one hundred fifty feet long, and it is possible that further exploration at this level would have discovered workable widths.

Composition of Mine Run of Fluorspar at Extension Mine in 1922

Quantity Sampled	CaF_2 Per cent	SiO_2 Per cent	$CaCO_3$ Per cent
40 cars	67.41	19.51	3.87
60 cars	71.57	8.77	2.60
6 cars	61.25	11.60	6.18

ZINC CONTENT

Commonly the ore of the Rosiclare vein carried only small amounts (less than 0.5 per cent) of sphalerite, but at some places in the Extension and Annex workings the ore carried as much as ten per cent. Sphalerite was most abundant in the north drifts of the Annex mine. During the operation of these mines 20,000 to 25,000 tons of the zinc-rich ore were stored, and after the mines were closed in 1924 it was run through an experimental mill. The tailings from this mill were too impure to be marketed for their fluorite content, and in 1926 they were being treated by flotation to recover a product running 93 per cent fluorite and 1.5 per cent silicia. The results of a test run at the flotation plant on September 1, 1926, are as follows:

	CaF_2 Per cent	SiO_2 Per cent	$CaCO_3$ Per cent
Feed	74.72	15.95	6.93
Concentrates	94.03	0.98	3 85
Tailings	55.08	29.93	11.34

The tailings also carried about three per cent of lead, iron, and zinc and were being saved for further flotation treatment.

RESERVES AND PRODUCTION

South of the New shaft the Rosiclare vein seems to be essentially worked out, except above the 200-foot level of the Extension and Annex workings where water prevents mining. Some ore still remains below the 281-foot level between the New and the Sweat shafts and between the No. 4 shaft and the Rosiclare workings, where bad ground delayed development. In the Rosiclare mine most of the ore above the 420-foot level is worked out, but below this level there are moderate reserves near the southern and the northern boundaries of the property and exploration has not defined the precise lower limit of the ore.

Fluorspar Production of Rosiclare Lead and Fluorspar Company

Includes the combined production from the Rosiclare and
Daisy veins and very minor additions from the
Empire mine and some prospects
(In short tons)

Year	Lump	Ground	Gravel	Total
1916	8566	3093	77357	89016
1917	9516	5957	88027	103500
1918	4033	5172	67126	76331
1919	565	6753	47536	54854
1920	5112	7865	49967	62944
1921	....	2802	8749	11551
1922	1611	5240	27210	34061
1923	4476	6958	36131	47565
1924	1309	3770	14019	19098
1925	1355	4258	25669	31282
1926	176	4730	22781	27687
1927	15	3955	21990	25960
1928 (to Oct 26 incl.)	1829	4415	13632	19876
Totals	38563	64968	500194	603725
Shipped 1909 to 1915 inclusive				283835
Shipped prior to 1909, problematical but roughly estimated at				50000
Total				937560

Approximately 176,000 tons came from the Daisy and Empire mines and small prospects, leaving nearly 762,000 tons as the total output from the Rosiclare vein.

HILLSIDE VEIN

(Secs. 29 and 32, T. 12 S., R. 8 E.)

The Hillside vein is a single persistent vein which has been followed continuously for more than sixteen hundred feet. It trends nearly north and south and dips so steeply to the west that it is nearly vertical. It varies from about five feet to thirty-five feet in width.

Many people have assumed that the Hillside vein is the northward continuation of the Rosiclare vein, but the divergence in their trend (Pl. II) and evidences of narrowing and impoverishment in both veins as they approach each other suggest that this assumption may be erroneous. Its truth can be proved only if underground workings establish a connection between them. However, if they are not directly continuous they may be connected by branch veins.

The Hillside vein is being exploited by the Hillside Fluorspar Mines Company, which was organized in 1919 after several years of exploratory work. In 1926 the Hillside mine was the largest producing mine in the region,

Throughout most of the mine the vein material adheres firmly to both walls, which are prevailingly limestone, and forms the sort of contacts known to the miners as "frozen" contacts. At a few places the west wall is a slick-

Fluorspar Production of Rosiclare Lead and Fluorspar Company

[illegible]

by branch veins.

The Hillside vein is being exploited by the Hillside Fluorspar Mines Company, which was organized in 1919 after several years of exploratory work. In 1926 the Hillside mine was the largest producing mine in the region, and was the only large vein mine accessible for study (Fig. 42).

MINE WORKINGS

The Hillside shaft which was begun in 1919 is a vertical shaft six by twenty feet in cross-section and five hundred twenty feet deep (1926). It is lined with concrete to a depth of 182 feet or below the level of loose or somewhat oxidized ground. Drifts at levels of 170, 250, 350 and 450 feet connect with this shaft (Pl. IV). A short drift at the 100-foot level connects with the surface through a subsidiary shaft. A vertical air-shaft nearly 900 feet north of the main shaft is six by twelve feet in cross-section and 450 feet deep. It connects with the 250- and 350-foot levels and is used for ventilation and subsidiary hoisting. The 350-foot level is longest (Pls. II and IV) and follows the vein for more than 1600 feet.

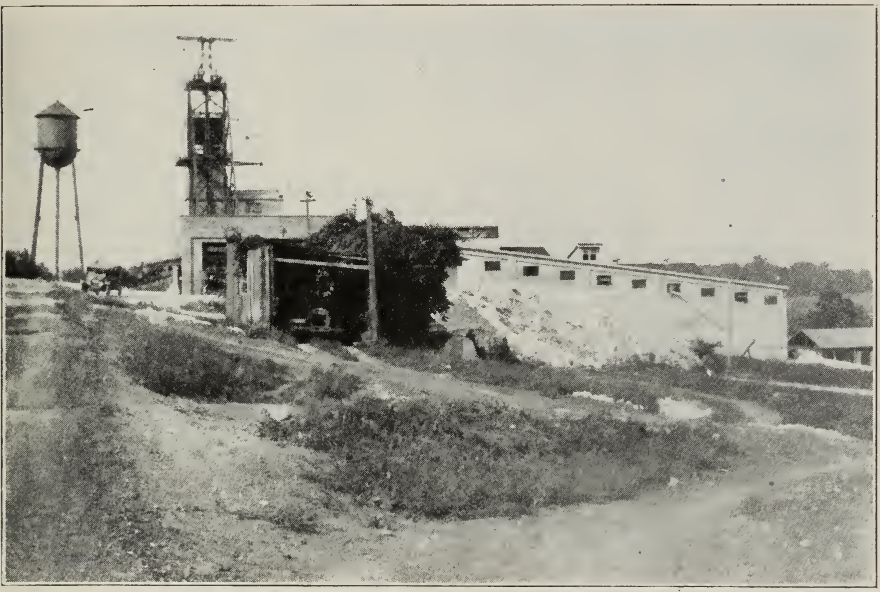

Fig. 42. Main shaft and mill of Hillside Fluorspar Mines Company, Rosiclare, Ill.

The 250-, 350-, and 450-foot levels were examined through their length. The 170-foot level was accessible for 100 feet north and 200 feet south of the main shaft. The 100-foot level was not accessible.

VEIN WALLS AND INCLUDED FRAGMENTS

Throughout most of the mine the vein material adheres firmly to both walls, which are prevailingly limestone, and forms the sort of contacts known to the miners as "frozen" contacts. At a few places the west wall is a slickensided fault-plane formed subsequent to mineralization. At most places there is little or no evidence that vein materials replaced the wall-rocks, but at one place there is a gradation from the usual vein material into finely banded material that is clearly a replacement of the limestone of the east wall (p. 14).

Fragments of wall-rock enclosed in vein material are not abundant in most portions of the vein, and at the few places where they are abundant they are commonly angular and are oriented in almost their original position (Figs. 19 and 43). They are usually associated with a horst of rock that divides the vein. At some places, however, the limestone fragments enclosed in calcite and fluorite show ragged outlines characteristic of replacement and the interior portions of such fragments have sometimes been so largely replaced by vein calcite that they may be described as pale and ill-defined "ghosts" of the original fragments. At some places smaller limestone fragments are notably rounded and shadowy in outline, whereas larger fragments are sharply angular.

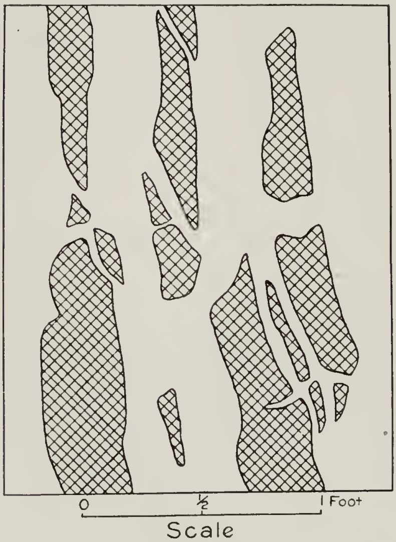

Fig. 43. Sketch showing limestone fragments near center of 25-foot vein in the stopes above the 350-foot level in the Hillside Mine. Note that the limestone fragments are not arranged hit or miss and apparently have moved not far if at all. They lie just above a horst of limestone that divides the vein.

Material on the dumps reveals stylolitic partings that traverse both ore and limestone. One six-inch specimen composed of coarse white calcite and a little fluorite is traversed uninterruptedly by a stylolitic parting; some of the original, oolitic gray limestone that was replaced by the fluorite and calcite is preserved in the stylolitic prongs and as a few adjacent fragments of ragged outline. In another specimen in which brownish-gray limestone was separated from light gray limestone by a stylolitic parting, a narrow wedge of calcite and purple fluorite has developed by selective replacement wholly on the gray limestone side of this parting and terminates sharply at the parting. In other specimens coarse calcite veinlets traversing limestone were observed to terminate lengthwise abruptly against a stylolitic parting. These data indicate that replacement has played a more important part in the formation of the Hillside vein than might be inferred from the prevailing "frozen" contacts.

VARIATION ALONG THE VEIN

On the 170-, 250-, and 450-foot levels the vein has become mainly calcite at distances respectively of 200, 190 and 20 feet south of the cross-cuts to the shaft, but the 350-foot level has been extended about 620 feet south of the shaft, the vein carrying considerable fluorspar for the entire distance.

By far the larger part of the production has come from north of the Hillside shaft. In that direction the vein is highly fluoritic for about 940 feet north of the shaft cross-cut on the 250-foot level, for more than 800 feet on the 350-foot level, and for 400 feet on the 450-foot level, beyond which distances it tends to become highly calcitic. However, on the 350- and 450-foot levels some fluorite persists to about 900 and 530 feet, respectively, from the shaft cross-cuts. On the 350-foot and 450-foot levels the vein forks about 550 feet and 450 feet, respectively, north of the shaft cross-cuts.

FAULTING AFTER MINERALIZATION

Little or no movement has occurred at most places along the Hillside vein, but on the 350-foot level and in the stopes above it a fault dipping westward at 65° to 70°, follows the west wall from a point about 170 feet north of the shaft cross-cut to the north face. This fault is a barren slickensided fracture zone. It was formed subsequent to the mineralization and in places brecciates vein material; in one place both walls of the fault are slickensided fluorite. The same fault is exposed from the shaft cross-cut north for about 450 feet on the 250-foot level. Bending of the beds on either side of this fault shows that it is a normal fault the west or hanging wall moving downward with respect to the east wall, and the grooves or slickensides pitching to the south at angles of 20° to 30° from the horizontal show the movement had also an important lateral component.

PRODUCTION

The Hillside mill was constructed at the mine in 1920, and actual production began in April, 1922. Both mine and mill are served by a spur of Illinois Central Railroad from Rosiclare. The production of fluorspar and of lead concentrates from the Hillside mine has been as follows:

Fluorspar Production of the Hillside Mine

(In short tons)

Year	"Gravel spar"	"Lump spar"	Lead concentrates
1922	9111	80	683
1923	21981	409	806
1924	16030	727	690
1925	9445	407	428
1926	16900	267	507
1927	14814	446	297

All of the "gravel spar" was sold as standard 85 per cent CaF_2 with silica content less than five per cent. Nearly all of the "lump spar" was of acid-making grade, having 98 per cent or more CaF_2.

All lead concentrates have been shipped to the National Lead Company at Collinsville, Illinois, for smelting and refining. They have averaged about 65 per cent lead and contain an average of five ounces per ton in silver.

BLUE DIGGINGS VEIN

(Sec. 32, T. 12 S., R. 8 E.)

The Blue Diggings vein lies about 900 feet west of and irregularly parallels the Rosiclare vein (Pls. I, II and V). Its strike varies from about N. 50° E. at the south to about N. 30° E. at the north. It dips to the southeast at angles commonly of 65° to 70°. Farther north, where the outcrop or apex of the vein has not been located, what is almost certainly the Blue Diggings vein is cut by a cross-cut west on the 412-foot level of the Daisy mine and has southeast dips of 55° to 65°. Vertical displacement along the vein has been about 100 feet, the east wall going down.

The Fairview Fluorspar and Lead Company worked the mine from 1910 to 1920, but since that time it has been idle and the workings could not be entered at the time of this survey (1926).

The vein is narrow, usually less than three feet, although occasionally five to eight feet wide; in its probable northward extension in the Daisy mine widths of five to twelve feet of fluorspar were noted. The fluorspar played out at the north faces of the 300- and 400-foot levels of the Blue Diggings workings and only about two feet of it showed on the deepest or 500-foot level, which was about 300 feet long. The portion of the vein on the property of the Franklin Fluorspar Company, which was developed

PRODUCTION

through the Blue Diggings workings, is said to be practically worked out, but the developments in the Daisy mine of the Rosiclare Company are very encouraging, and it is possible that considerable tonnages will be won from this northern portion of the vein.

About 100 tons of ore from the Blue Diggings vein was obtained in the summer of 1925 when a cross-cut on the 500-foot level was driven to the Argo vein and showed 57 per cent of calcium fluoride, 29 per cent of silicon dioxide, and 11 per cent of calcium carbonate. The total production from the Blue Diggings shaft workings has been about 259,000 tons.

APPEARANCE OF BLUE DIGGINGS VEIN IN THE DAISY MINE

A cross-cut about 300-feet long driven west on the 412-foot level of the Daisy mine cut what is probably the Blue Diggings vein, and by October, 1928, about 2100 feet of drifting had been done along the vein on the 412-foot level and more than 900 feet on the 500-foot level (Pl. VI). The vein dips southeast at angles of 50° to 65°. Pronounced upward flexing of shale beds forming the east or hanging wall shows that it had gone down with respect to the west wall. The widths of fluorspar exposed in 1926 ranged from 5 to 14 feet. Where it was 14 feet wide 1½ feet of calcite inclosing angular fragments of limestone lay next to the footwall, above this was two feet of purple fluorspar, and then twelve feet of white to gray fluorspar. Several slickensided fracture planes cutting the fluorspar show that there was movement along the vein subsequent to the mineralization.

Argo Vein

(Sec. 32, T. 12 S., R. 8 E.)

The Argo vein on the property of the Franklin Fluorspar Company, is about 400 feet northwest of and roughly parallels the Blue Diggings vein (Pls. I and II). At the shaft it dips steeply to the northwest. The vertical displacement along the vein is about 100 feet, the west or hanging wall having gone down with respect to the east wall.

This vein was discovered by churn drilling in 1922. A shaft was sunk upon it, and in 1923 a cross-cut from the 500-foot level of the Blue Diggings shaft was driven west to it. Although seven feet of fluorspar occurred at places, the vein has as yet been little worked or prospected, partly because much of the vein material is loose and can be held only by square-set timbering. Commonly the vein is five to eight feet wide.

The vein and adjacent walls are characterized by cavernous openings of extraordinary size. One cavity in limestone wall-rock was 60 feet long, 30 feet high, and as much as 15 feet wide. It was lined with pyrite of radiating structure on top of which crystals of calcite were deposited which in turn were partly coated with pyrite. South of the shaft a large cavity, in places 30 feet wide, extended 150 feet along, 45 feet above, and 30 feet below the 100-foot level. It was lined with radiating pyritic crusts one-half inch thick, on top of which crystalline calcite had been deposited.

Materials on the shaft dump showed no unusual features. In general the ore appears to have been unusually rich in calcite. Argo ore milled from December 14, 1925 to January 9, 1926, ran 47 per cent calcium fluoride (CaF_2), 6 per cent silicon dioxide (SiO_2), and 45 per cent calcium carbonate ($CaCO_3$). This is about as calcareous an ore as is milled in this district.

Daisy Vein

(Sec. 32, T. 12 S., R. 8 E.)

The Daisy vein lies about 600 feet west of and nearly parallels the northern part of the Rosiclare vein (Pls. I and II). It strikes at an acute angle to the Hillside vein which it may join north of the present workings. It dips west at angles of 70° to 80°. At most places it does not exceed eight feet in width, but at a few places it widens to about 20 feet.

It is developed by the Daisy mine of the Rosiclare Lead and Fluorspar Mining Company. The main operating or No. 2 shaft is about 600 feet northwest of the Hillside shaft.

In 1926 the most extensive developments and the best exposures were on the 412-foot level (Pl. VI). The 180-foot level was accessible only south of the shaft, and the 300-foot level could not be entered. The deepest exposures are on the short 500-foot level, which is reached by a winze from the 412-foot level.

Throughout most of the workings the west or hanging wall is a post-mineralization fault plane, as fault fractures clearly traverse and brecciate fluorspar and calcite at some places. The pitch of pronounced slickensides or striations varies from 10° to the south to 80° to the north, showing that the movements along the fault were different in direction at different times. Flexing of beds near the fault plane shows that the west wall has gone down with respect to the east wall. On its east or foot wall the vein material is commonly firmly attached or, in miner's parlence, "frozen" to the wall (Fig. 3, p. 14).

Evidences of replacement are not conspicuous in the Daisy vein, but careful examination of material on the dumps revealed some examples of (1) limestone fragments inclosed by vein calcite and fluorite, (2) stylolitic partings forming the boundary between limestone and vein materials or passing continuously from limestone into a calcite-fluorite aggregate, and (3) limestone breccia in which the larger fragments are sharply angular but the smaller fragments are prevailingly rounded or have ragged hazy outlines.

The vein comprises repeated alternations of portions dominantly fluorite and portions dominantly calcite or with little mineralization of any sort. On the 412-foot level, which could be studied only to within about 300 feet of the south face, the mineralization appeared to be weakening to the south,

stopes between the 412- and 500-foot levels.

PRODUCTION

The approximate production of finished fluorspar from the Daisy mine as computed from the tonnage of crude ore hoisted and the average percentage of recovery is shown in the following table:

radiating structure on top of which crystals of calcite were deposited which in turn were partly coated with pyrite. South of the shaft a large cavity, in places 30 feet wide, extended 150 feet along, 45 feet above, and 30 feet below the 100-foot level. It was lined with radiating pyritic crusts one-half inch thick, on top of which crystalline calcite had been deposited.

Materials on the shaft dump showed no unusual features. In general the ore appears to have been unusually rich in calcite. Argo ore milled from December 14, 1925 to January 9, 1926, ran 47 per cent calcium fluoride [illegible]

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Evidences of replacement are not conspicuous in the Daisy vein, but careful examination of material on the dumps revealed some examples of (1) limestone fragments inclosed by vein calcite and fluorite, (2) stylolitic partings forming the boundary between limestone and vein materials or passing continuously from limestone into a calcite-fluorite aggregate, and (3) limestone breccia in which the larger fragments are sharply angular but the smaller fragments are prevailingly rounded or have ragged hazy outlines.

The vein comprises repeated alternations of portions dominantly fluorite and portions dominantly calcite or with little mineralization of any sort. On the 412-foot level, which could be studied only to within about 300 feet of the south face, the mineralization appeared to be weakening to the south, and to the north the vein becomes increasingly rich in calcite beyond a point about 700 feet from the shaft cross-cut. Although fluorspar has been stoped from between the 412- and 500-foot levels, the vein as exposed on the 500-foot level is highly calcitic, but it is strongly developed and well defined, being about 20 feet wide at one place. At several places on this level both walls of the vein are "frozen" to the wall-rock. One of the widest exposures of the vein was in stopes 40 feet above the 200-foot level and a little south of the shaft, where 17 feet of vein material was shown. Next to the west or hanging wall is seven feet of gray fluorite, east of which there is eight feet of sheared shale with which much fractured purple fluorite is mixed.

About 1850 feet south from the shaft cross-cut on the 412-foot level a cross-cut about 300 feet long leads westward and taps what is almost certainly the Blue Diggings vein (p. 77). A second cross-cut about 330 feet long has been driven west from a point about 550 feet north of the shaft cross-cut on the same level, but it encountered only a few narrow calcite-fluorite veinlets of no commercial consequence. Another cross-cut on the 412-foot level has been driven in a southeasterly direction nearly to the property line between the Daisy and Hillside mines, where it turns due south and parallels the line for about 330 feet. The only veins encountered were nearly vertical calcite veins a few inches to one foot wide, some of which carry a little purple fluorite. They occur close to the property line and are probably offshoots from the Hillside vein which lies only a short distance to the east.

Solution channels in calcitic portions of the vein are well shown in the stopes between the 412- and 500-foot levels.

PRODUCTION

The approximate production of finished fluorspar from the Daisy mine as computed from the tonnage of crude ore hoisted and the average percentage of recovery is shown in the following table:

Production of finished fluorspar from Daisy mine

	Short Tons
Prior to 1918 approximately	1400
1918	9786
1919	8037
1920	17107
1921	1075
1922	1537
1923	12835
1924	18322
1925	21490
1926	22795
1927	21791
Total	136175

DIMMICK PROSPECT SHAFT NO. 2
(SE. ¼ Sec. 29, T. 12 S., R. 8 E)

The Dimmick No. 2 shaft (Pls. I and II) of the Rosiclare Lead and Fluorspar Mining Company, is located a little less than half a mile north of the Daisy shaft. It is 65 feet deep, and from its bottom a drift extends southeast for about 80 feet, all in shale. A fault zone 1½ to 3 feet wide was encountered about 30 feet from the shaft. No mineralization was noted in the workings.

EUREKA FLUORSPAR MINE
(NW. ¼ sec. 28, T. 12 S., R. 8 E.)

The old Eureka shaft, now called the Eureka No. 1 (Pl. I), was long abandoned and was inaccessible in 1926, but it has since been reopened by the Rosiclare Lead and Fluorspar Mining Co. The vertical shaft was 220 feet deep in October, 1928. A level at 150 feet extended west but not east and connected with the Eureka No. 2 or Cowsert shaft. From this level overhead stoping in two stopes has been carried to within 40 to 50 feet of the surface.

The Eureka No. 2, formerly called the Cowsert shaft, lies about 850 feet west of State Highway No. 34. It was about 310 feet deep with levels at 48, 80, 200, and 300 feet in October, 1928. One small stope had been started from the 200-foot level, which is the same as the 150-foot level of Eureka No. 1. In 1926 the shaft was only 45 feet deep but it exposed a vein striking N. 30° E. and dipping 85° northwest. The vein follows a fault, as the northwest wall was shale and the southeast wall was sandstone. The vein was well defined and in places had four to six feet of nearly pure fluorite. At one place two to three inches of galena paralleld a 6-inch vein of fluorite.

Subsequent stoping has revealed three to five feet of fluorspar in the stopes above the 200-foot level.

Two other shafts, Eureka No. 3 and No. 4, farther south on the same vein are 250 and 200 feet deep respectively. Eureka No. 4 lies about 840 feet north of the Hillside property line. In 1928 no drifts had been run from No. 3, and only 350 feet of drifting had been done from No. 4.

The Eureka mines yielded 1276 short tons of finished spar in 1927 and 3784 tons in the first nine months of 1928.

CLEMENT-DYSPECK PROSPECTS

(SW. ¼ sec. 21, T. 12 S., R. 8 E.)

The Clement-Dyspeck prospects (Pl. I) of the Rosiclare Lead and Fluorspar Mining Company lie about two miles north of Rosiclare and northeast of the State Highway Route 34. They are this company's most northeastern development along the Rosiclare-Hillside vein system.

The exposed vein follows a fault striking N. 45°-50° E., and of nearly vertical dip. It is apparently the same vein developed farther southwest by the old Eureka workings. It is developed by several small open pits and by a shallow shaft from which a single level, 40 feet below the shaft collar, has been driven. Slickensides and brecciated limestone fragments show that there has been movement along the vein, and rounded solution surfaces of limestone indicate that ground waters circulating along the fault have attacked the limestone. The shaft workings at places expose 4 feet of vein material, which consists of several narrow veinlets of fluorite traversing iron-stained clayey material. Up to October, 1928, this property had yielded slightly more than 1600 tons in finished spar.

INDIANA OR HILLSIDE NO. 2 MINE (abandoned)

(SW. ¼ sec. 19, T. 12 S., R. 8 E.)

The Indiana or Hillside No. 2 mine (Pl. I) lies two and a half miles north and northwest of Rosiclare. The mine is owned by the Indiana Fluorspar and Lead Company and from 1923 to 1925 was operated under lease by the Hillside Fluorspar Mines.

The property develops two nearly parallel veins about 130 feet apart at the surface. They strike N. 18° E. and dip steeply to the west, the west one more steeply than the east one. The west vein is developed by a vertical shaft about 100 feet deep, from which drifts have been run northward at 30- and 100-foot levels. A cross-cut from the 100-foot level taps the eastern vein but little mining has been done in it.

The dump shows abundant coarse calcite and white, gray, and purple fluorite. At some places a little galena occurs in irregular veinlets in the calcite.

While the Indiana mine was operated by the Hillside Fluorspar Mines it produced 5308 short tons of gravel spar. Its output prior to this period was probably about 600 tons.

MARTIN MINE (idle)

(NW. ¼ NE. ¼ sec. 17, T. 12 S., R. 8 E.)

The Martin mine (Pl. I) lies along the west side of the valley of Big Creek three miles northwest of Elizabethtown. The property is controlled by the Rosiclare Lead and Fluorspar Mining Company. A caved shaft and several small open pits line up in a direction about N. 20° E. which probably represents the approximate trend of the vein. The property is close to a fault which brings the St. Louis limestone in contact with sandstones of the Caseyville formation.[1]

Most of the material on the dump is much weathered but some limestone blocks showed intersecting sharp veinlets of calcite and fluorite. The rock at the shaft and southeast of the vein seems to be mostly sandstone (probably Caseyville), which is traversed by seams of pyrite that oxidize and give a sulfurous odor to the dump. The property produced 558 short tons of finished spar in 1925 and 1926 and perhaps 400 tons previous to those years.

WEBBER-WOOD MINE

(SW. ¼ SE. ¼ sec. 18, T. 12 S., R. 8 E.)

The Webber-Wood mine (Pl. I) lies three and a half miles north and northwest of Rosiclare. Several shallow shafts and pits line up in a direction N. 20° W. which appears to be the approximate strike of the vein. Development work has followed the vein for about 200 feet. The mine is equipped with a small steam hoist at the main shaft and with a log-washer. The washed spar was hauled to the railroad siding at Stewart mine.

PREEN PROSPECT (abandoned)

(NW. ¼ sec. 19, T. 12 S., R. 8 E.)

The Preen prospect (Pl. I) lies about three miles north-northwest of Rosiclare. A few shallow pits line up in a north-south direction. A small shaft is said to be at least 75 feet deep. A few small stringers of fluorite in limestone were noted on the dump.

TWITCHELL MINE (abandoned)

(NE. corner sec. 24, T. 12 S., R. 7 E.)

The Twitchell mine (Pl. I) lies about three miles northwest of Rosiclare. Three shallow shafts line up in a direction N. 10° E., which is probably the approximate trend of the vein. The vein dips east. The deepest

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[1] Weller and associates, Op. cit., Pl. I.

shaft is about 60 feet deep. The dumps show veinlets of calcite and fluorite sharply cutting limestone.

Pell Mine

(NE. ¼ NW. ¼ sec. 24, T. 12 S., R. 7 E.)

The Pell mine (Pl. I) is located about four miles northwest of Rosiclare. An old shaft said to be at least 95 feet deep develops a vein that appears to strike about N. 25°-30° E. The ruins of an old mill adjoin the shaft.

The old dumps carry coarse calcite, gray fluorite, galena, and sphalerite. A small stock pile contains several tons of ore apparently picked for its high galena content.

Advices in October, 1928, indicated that the mine had been reopened to develop portions of the vein lying northeast of the old workings.

Stewart Mine

(Near center sec. 14, T. 12 S., R. 7 E.)

The Stewart mine (Pl. I) lies five miles northwest of Rosiclare. It was in operation in 1917 but in 1926 it had been idle for several years. The vein strikes N. 25° E. and dips 80° E., and follows a fault, as at a depth of 25 feet limestone formed the west and sandstone the east wall. The width of the vein ranges from 2 to 4 feet. The property was developed by open pits and by two shafts said to be at least 75 and 100 feet deep respectively.[2]

The rock in the dump is mainly gray limestone, of which some has been brecciated and the fractures filled with calcite and fluorite, showing clearly that there has been little or no replacement. In other pieces on the dump, limestone grades without sharp boundaries into a coarse association of pyrite and fluorite, suggesting replacement.

Solution of calcite near the surface has rendered the vein material porous, and limonite, doubtless an alteration product of pyrite, occurs in stalactite forms in the cavities.

Baker or Eichorn Mine

(NE. ¼ sec. 14, T. 12 S., R. 7 E.)

The Baker mine (Pl. I) is about five miles northwest of Rosiclare. It is developed by a shaft said to be 330 feet deep. Some drifting has been done on the 200-foot level and cross-cuts run on both the 100-foot and 200-foot levels. The owners, the Eichorn Fluorspar Mining Company of Golconda, Illinois, last worked the property about 1923. In 1926, Knight Brothers and E. C. Clark, lessees, pumped it out to the 100-foot level, but mining was not resumed.

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[2] Currier, L. W., Part V—Economic Geology, "Geology of Hardin County," Ill. State Geol. Survey, Bull. 41, p. 300, 1920.

Small amounts of ore on the dump were similar to that at the Stewart mine. Apparently the production has been small.

ROSE MINE (abandoned)
(SE. ¼ sec. 30, T. 11 S., R. 8 E.)

The Rose mine (Pl. I) lies near Hicks School, about eight miles north of Rosiclare. Two open pits, 20 feet in maximum depth, one about 25 feet by 100 feet and the other 25 feet by 75 feet, constitute the principal development work. A small steam shovel was used in excavating the pits. A caved shaft said to be about 100 feet deep is not on any vein.

Fluorite in place was seen only near the center of the larger pit where three feet of pure fluorite was exposed. The yield of the mine was wholly "gravel spar" which was won from the weathered incoherent surface material.

HAMP MINES (abandoned)
(NW. corner sec. 18, T. 11 S., R. 8 E.)

The Hamp mines (Pl. I) are about two miles west-southwest of Karbers Ridge, and about ten miles north of Rosiclare. The property is developed by shallow shafts, most of which are in or near a vein striking nearly east-west and dipping to the south at angles of 60° to 75°. From west to east these shafts are Hamp No. 2, 30 feet deep; Hamp No. 1, 100 feet deep; and Wormach, 140 feet deep. Veins six inches to nine feet wide and fluorspar six inches to seven feet wide are said to have been found in a drift 155 feet long connecting with the Wormach shaft. Near the west end of the Hamp vein is another vein striking about N. 15° W. and developed by an 80-foot shaft. A shaft about 550 feet east of the Wormach shaft is 118 feet deep and is said to be on a northwest-southeast vein. Two open cuts and a 20-foot shaft about 1200 feet north of the Wormach shaft develop what is said to be a blanket deposit of fluorite.

The mine was discovered by Captain J. W. Waggoner of Karbers Ridge and was opened up in 1897. It was sold to the Franklin Fluorspar Company and later the U. S. Steel Corporation prospected it with diamond drills. It is now owned by the Roger Sullivan estate.

According to Captain Waggoner the property has produced 7000 to 8000 tons of fluorspar. The spar was milled on the property, and the concentrates were hauled by truck eight miles to the railroad siding at Stewart mine. Two-ton trucks made three trips a day.

LEE MINE
(NW. ¼ NW. ¼ sec. 14, T. 11 S., R. 8 E.)

The Lee mine (Pl. I) is located two miles east-southeast of Karbers Ridge. As seen in shallow shafts and cuts the vein strikes N. 58° E., dips southeast at angles of about 70°, and has a width of seven to eight feet. Only oxidized portions of the vein were visible. The west shaft is 100 feet deep. No drifting has been done on the vein, but it has been traced on the surface for about 1000 feet. It follows a pronounced fault and at the mine Cypress sandstone forms the northwest wall and Menard limestone the southeast wall.

A mill now partly dismantled is located near the mine and is equipped with crushing rolls and a log-washer. Jigs formed part of the equipment but have since been removed.

About 600 tons of jig concentrates said to run about 96 per cent fluorite were stored at the mine ready to be hauled to the Stewart mine siding for rail shipment.

Eureka Lead Mine (abandoned)
(SW. ¼ sec. 23, T. 11 S., R. 9 E.)

The Eureka lead mine (Pl. I) is about five miles north of Cave in Rock. It appears to be on a prominent fault that passes east of Mt. Zion church.[3] The mine is the property of the Eureka Lead Company, Mt. Carmel, Illinois. Two vertical shafts, both of which are now inaccessible, have been sunk. The east shaft was sunk about 1905 by Mr. W. J. Rogers. It is reported to be 55 feet deep and a cross-cut from the bottom extending 28 feet to the northwest is said to be entirely in vein or fault material. The west shaft was sunk later by John E. Hanon to a depth of about 80 feet, but no drifts were driven.

Ore on the dump shows in order of abundance calcite, sphalerite and fluorite, and galena, which form veins in fossiliferous limestone. The east shaft yielded a little lead and zinc ore which was shipped. Fluorspar was found only in the west shaft and was not abundant.

F. E. Martin Prospect
(SW. corner sec. 23, T. 11 S., R. 9 E.)

The F. E. Martin prospect (Pl. I) five miles north of Cave in Rock consists of a vertical shaft 38 feet deep. Sandstone and limestone on the dump are traversed by veinlets mainly quartz and calcite but carrying some fluorite and galena and a little chalcopyrite.

Douglas Mines (idle)
(Center sec. 34, T. 11 S., R. 7 E.)

The Douglas mines (Pl. I) are about seven and a half miles northwest of Rosiclare. Several shafts and open pits are aligned in a direction N. 42° E. which may represent the approximate trend of the vein. At the main shaft are twin log-washers feeding to shaking screens. About 500 feet west

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[3] Weller, Stuart, and associates, Op. cit., Pl. I.

of the plant is another, water-filled vertical shaft and a mill in good condition. There were no surface indications from which the direction of the vein could be determined.

The material on the dump shows calcite and fluorite generally in sharp contact with gray limestone and clearly filling fractures in it, but in some cases isolated crystals of calcite and fluorite in their characteristic forms have clearly been deposited by replacement. Gray quartz is an occasional accompaniment of fluorspar in vugs.

Pierce Mine (abandoned)
(NE. ¼ sec. 34, T. 11 S., R. 7 E.)

The Pierce mine (Pl. I) lies about half a mile south of the Empire mine. Little concerning the vein or veins could be learned from the old open cuts but the principal vein appears to trend about N. 45° E.

Empire Mine
(SW. ¼ SE. ¼ sec. 27, T. 11 S., R. 7 E.)

The Empire mine (Pl. I) is located about eight miles northwest of Rosiclare. The workings (Fig. 44) develop a well-defined vein striking N. 55° E. and dipping 70° southeast.

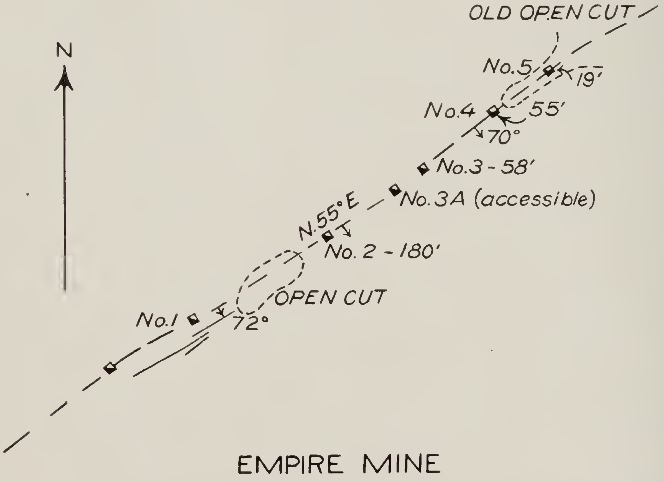

Fig. 44. Plan showing position of shafts and pits at the Empire Mine.

The only shaft operating in 1926 and accessible for examination was No. 3A. It is a vertical shaft 48 feet deep from the bottom of which drifts were driven along the vein southwest for about 70 feet and northeast for about 50 feet. The shaft penetrated clay and Rosiclare sandstone for the first 20 feet, below which it entered Fredonia limestone. The vein as exposed in these workings is two to three feet wide. A characteristic exposure shows a band of fluorite two feet wide in sharp contact with the limestone of the footwall. Most of the fluorite is gray but the three inches nearest the footwall is purple. Between the fluorite band and the limestone of the hanging wall is one foot of white calcite in crystals up to two inches across. The contact between the fluorite and calcite bands is not sharp. At another exposure a central 3-foot band of fluorite is bordered above by 1½ feet of calcite and below by six inches of calcite. A little galena is present in the calcite. Material in the dump of this shaft shows some resin sphalerite which has replaced the limestone walls and the limestone fragments in the vein. A little zinc carbonate ore was formerly found in the surface clays. Some movement along the vein subsequent to mineralization is shown by slickensided fractures traversing the calcite.

The Empire mine is operated by the Rosiclare Lead and Fluorspar Mining Company. The vein material as mined is loaded into 1-ton trucks and hauled to the railroad siding at Stewart mine, and from there it is shipped to the company's mill at Rosiclare. The production of finished fluorspar from the Empire mine as computed from the tonnage of crude ore and the average percentage of recovery was as follows:

Production of finished fluorspar from Empire mine

Year	Short Tons
1924	776
1925	4778
1926	1999
1927	287

WALLACE MILLIKAN PROSPECT

(SW. ¼ sec. 27, T. 11 S., R. 7 E.)

About a quarter of a mile northwest of the Empire vein, prospect pits opened by Wallace Millikan expose 14 to 18 inches of fluorite, which is apparently in a vein about parallel to the Empire vein, although the exposures are not sufficient to indicate its trend clearly. No mining has been done.

KNIGHT MINE

(Center north line sec. 34, T. 11 S., R. 7 E.)

The Knight mine (Pl. I) develops a southwestward extension of the Empire vein. About 820 feet of the vein is included within the boundaries of the property. In 1926 a vertical shaft 60 feet deep had been sunk just west of the vein, and from the bottom of the shaft a cross-cut was being driven to intersect the vein. The property was being developed by A. D. and E. A. Knight of Rosiclare.

Later advices indicate that the property was operated until December 1, 1927. Levels were turned off from the shaft at depths of 44 to 120 feet. Drifts were extended north about 220 feet, to the Empire property line, and south about 120 feet, and a little stoping was done. This development revealed fluorspar 2½ to 4 feet wide. About 500 tons of finished fluorspar was produced.

Baldwin Mine (abandoned)

(SE. ¼ NE. ¼ sec. 27, T. 11 S., R. 7 E.)

The Baldwin mine (Pl. I) is about half a mile north of the northernmost workings of the Empire mine. A small pit exposes an 8-inch vein which strikes N. 50° E. and dips 70° southeast. The vein is an irregular association of calcite and fluorite with occasionally some galena and sphalerite. Specimens on the dump show that sphalerite and fluorite have replaced fractured limestone of the walls. The weathered surface portions of the vein yielded a small amount of "gravel spar" which was treated by log-washer. The vein appears to be too narrow to justify mining. A shaft about 50 feet deep has been sunk to one side of the vein.

Crabb Prospect (abandoned)

(Center sec. 27, T. 11 S., R. 7 E.)

The Crabb prospect (Pl. I) is a vertical shaft about 40 feet deep that could not be entered. It appears to develop a vein striking N. 45° E. and dipping southeast. The shaft passes through Bethel sandstone and enters O'Hara limestone. The dump shows purple fluorite, calcite, galena, and considerable sphalerite. The property was formerly worked by A. D. Pierce's sons, of Golconda, Illinois.

Big Joe Prospect (abandoned)

(NW. ¼ sec. 27, T. 11 S., R. 7 E.)

The Big Joe prospect (Pl. I) is situated on the east slope of the valley of Big Grand Pierre Creek. Several hillside pits expose a nearly vertical vein of fluorite as wide as six to eight inches which strikes N. 20° E.

About an eighth of a mile north of the workings a trench about 150 feet long was excavated many years ago and follows what may be the same vein. The trench is cut in Cypress sandstone and the dump shows some white and purple fluorite.

CHAPTER VI—MINE DATA, BLANKET DEPOSITS

SPAR MOUNTAIN MINES

(NW. ¼ sec. 3, NE. ¼ sec. 4, T. 12 S., R. 9 E.)

The Spar Mountain Mines (Pls. I and VII) are located three and a half miles northwest of the village of Cave in Rock. The workings are distributed along the south and southeast slopes of Spar Mountain, a relatively flat-topped hill which rises to an elevation of about 650 feet. The property is the largest of the blanket deposits and the only one that was being worked in 1926. It offers by far the best opportunity for studying this type of deposit and the management courteously facilitated that study in every possible way. The property was originally opened between 25 and 30 years ago by the Cleveland-Illinois Fluorspar Company, which operated it mainly as a lead mine although fluorspar was also saved. In 1919 it was operated exclusively for fluorspar by Spar Mountain Mining Company of New York. This company was succeeded by Benzon Fluorspar Company of 105 South La Salle St., Chicago, Illinois, incorporated in Illinois in 1926. Mr. John W. H. Blee of Cave in Rock is manager.

The principal workings at Spar Mountain (Pl. VII) include underground drifts, flat stopes or galleries, and open pits. The principal underground developments are the Cleveland and Lead workings. Open-pit workings also develop outcropping portions of the Cleveland ore body, and to open-pit workings farther west the names West Morrison and Oxford are applied. The more general features of the ore bodies have been described (pp. 45-65).

The West Morrison adit workings (Pl. VII) extend eastward from the portal into the hill for not more than 100 feet and are in mostly lean or barren ground. At the entrance, Rosiclare sandstone becomes thin-bedded and includes shaly layers which at some places are a foot thick. Neither sandstone nor shale has been replaced by fluorite but an occasional small fluorite veinlet cuts across them. Just below the shale there is 4 feet of banded replacement ore in which the bands nearly parallel the bedding of the shale and in which a few thin sandstone partings occur. The finer bands are calcareous, indicating incomplete replacement of limestone.

The West Morrison open pits (Pl. VII) exploit loose material that consists of blocks of fluoritic material and of sandstone in a clayey matrix, all of which is probably derived by the weathering of a fluoritic zone just below the Rosiclare sandstone. Some of the pits, however, develop an unaffected fluoritic zone lying about 25 feet below the level of the Rosiclare sandstone.

The Oxford pits contain fluorite blocks in residual clays, which represent the weathered products of fluorite-bearing limestone extending from the Rosiclare sandstone at the top to what is known locally as the sub-Rosiclare sandstone about 40 feet below.

At one of the open pit workings (Pl. VII, and Fig. 45) at the Cleveland mine, about 25 feet of intermittently fluorite-bearing material, somewhat weathered but essentially in place, is exposed below the level of Rosiclare sandstone and its basal shale beds. Zones of banded fluorite up to two feet wide alternate with flat-lying lenses of nearly barren sandy limestone. A little granular white barite is associated with the fluorite at a few places.

Fig. 45. Open pit at Spar Mountain, Benzon Fluorspar Company.

Mining methods at Spar Mountain are described on page 97. Winter mining is carried on mainly underground but in the summer mining is almost restricted to open pits. From the mine the fluorspar is hauled five miles to the mill at Cave in Rock at a cost of about $1.25 per ton in 1926. Coal for operating the mill and the steam plant at the mine is transported from the Kentucky coal fields to Cave in Rock by barges on Ohio River. The season for open-pit mining is usually the nine months from April to December inclusive, the roads being impassable at other seasons.

Milling methods at Cave in Rock are described on page 99. The mill products consist of acid spar and of ordinary spar, which are shipped in

bulk by barges on Ohio River to Shawneetown. At Shawneetown the ordinary grades are crushed to one inch or less in size for shipment by rail to the markets. Shipments go as far west as Midvale, Utah, and as far east as Long Island, New York.

The grade of the fluorspar (not including "acid spar") produced at Spar Mountain is shown by the following monthly averages of the mill product, which are obtained from daily analyses (see p. 100) of a composite sample made up of cuts taken from the combined log-washer and picking-belt products at half hour intervals.

Monthly averages of mill product of the Benzon Fluorspar Company

	CaF_2			SiO_2			$CaCO_3$		
1926	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min	Av.
April	90.28	83.32	88.95	6.60	3.90	4.74	9.20	4.00	5.45
May	91.82	84.73	89.03	6.85	3.80	5.12	9.20	2.80	5.12
June	92.12	84.30	88.73	6.80	4.10	5.16	11.40	2.05	5.32

The production of the Spar Mountain mines from 1919 to the middle of 1926 is said to have been 92,463 short tons of crude spar, equivalent to about 78,700 short tons of finished product. According to Mr. Blee, the production of the property prior to 1919 did not exceed 7500 short tons of finished product. Reserves are estimated by Mr. Blee at 60,000 to 80,000 short tons.

Green and Defender Mines (idle)

(SW. ¼ SE. ¼ sec. 34, T. 11 S., R. 9 E.)

The Green and Defender mines lie just northeast of the Cleveland mine (Pls. I and VII). The Defender workings were developed through a shaft that could not be entered. The Green mine workings are entered through an adit and develop a deposit of the blanket type similar to the deposit at Cleveland mine, although the mineralization is notably weaker. No coarsely crystalline ore was seen in the workings. The banded ore is generally not as thick as that in the Cleveland mine and some of it is notably limy, so that it is evidently a product of incomplete replacement of the limestone. The roof is Rosiclare sandstone and its basal shale, and the rock beneath the ore is Fredonia limestone.

Samples from the two zones of banded ore (locality 7, Pl. VII) showed that the replacement was nearly complete in the upper zone, as the fine-grained bands consist largely of fluorite with a little quartz and very little calcite, whereas in the lower zone the fine-grained bands contain abundant calcite.

Victory Fluorspar Mine

Since 1926 mining on an adjoining property north of the Benzon Company's workings has been begun by the newly organized Victory Fluorspar

Mining Company, of which Mr. Martin Schwerin is president and general manager. The workings include several thousand feet of drifts reached through a shaft 160 feet deep. These workings and also extensive diamond drilling has shown the presence of large quantities of fluorite, which at some places constitutes a single blanket deposit 10 to 17 feet thick but elsewhere it consists of two blanket deposits separated by several feet of limestone.

The crude fluorspar is treated in a simple plant at the shaft having a capacity of 12 tons per hour. In this the fluorite is first crushed, then washed in a trommel, from which the oversize passes over a picking belt and the undersize passes through a log-washer. The overflow from the log-washer is classified. Most of the finished spar is hauled by truck to Rosiclare but part of it is hauled to Stewart Siding near Eichorn.

Up to December 1, 1929, about 15,000 short tons of finished spar had been produced. Preparations are being made for barge shipment on Ohio River as recent construction of dams in the river has made navigation possible even in low water stages.

Crystal Fluorspar Mine

The Crystal Fluorspar Company reported in January, 1931, that it was developing a blanket deposit adjoining on the north and east that of the Victory Fluorspar Mining Company. Eight men were employed and the early erection of a mill was contemplated.

Cave in Rock Mine

(NW. ¼ NE. ¼ sec. 4, T. 12 S., R. 9 E.)

The Cave in Rock mine (Pl. I) is about four miles northwest of the village of that name. The deposits are of the blanket type and are exploited by irregular drifts (Fig. 46) and flat-lying stopes, many of which are unsafe to enter or are under water. A sub-level was filled with water.

In general the workings exploit a replacement deposit in limestone below a thin sandstone capping a few inches to three feet in thickness with which a few thin shale beds are associated and served to render it relatively impervious and resistant to the replacing solutions. The fluorite mineralization immediately below the capping is relatively coarse and constitutes the highest grade material of the mine; below this the banded fluorite ore is a product of rhythmic replacement of the limestone. The mineralization is similar in type to that at the neighboring Spar Mountain mines.

About 200 feet west of the portal of the workings is another series of underground workings entered by an incline. These were unsafe and could not be studied in detail, but they develop a replacement deposit apparently at a slightly higher horizon than the main workings described above.

A third series of drift workings near the crest of the hill lie just below Rosiclare sandstone. These drifts penetrate the hill in a direction generally

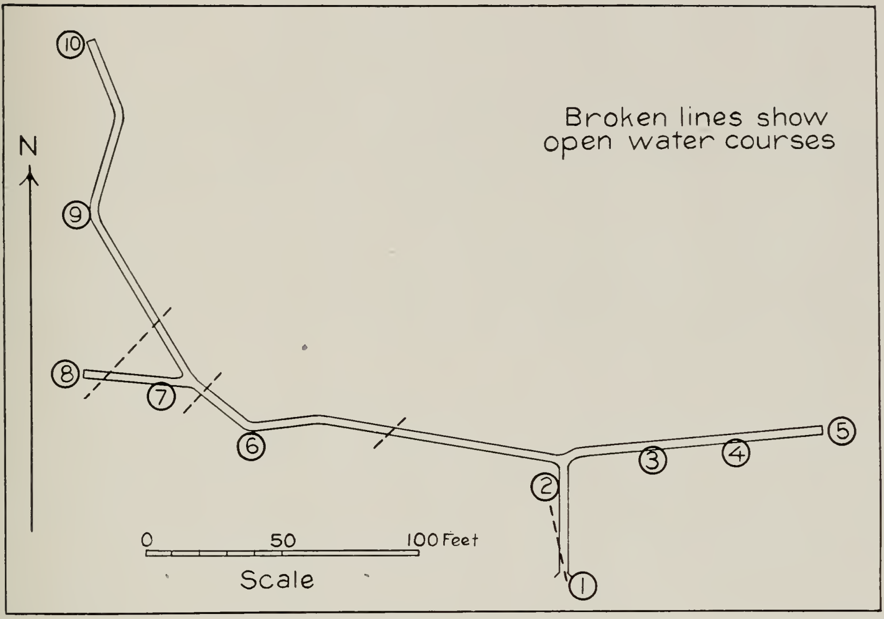

Fig. 46. Plan of lower workings of Cave in Rock Mine, plotted from pacing and hand compass survey. Numbers in circles refer to descriptions as follows:

1. Open pit at the portal of the workings.
2. One foot of coarse fluorite next to roof, with three feet of banded ore below.
3. One foot of coarse fluorite next to roof, with two feet of banded ore below.
4. Three feet above level of track is one foot of sandstone, above which is fine-grained limestone carrying vugs lined with crystals of fluorite but carrying no banded ore, and below which is one foot of coarse pure fluorite and one foot of banded flurite ore.
5. One and one-half feet of banded ore carrying scattered galena at face.
6. One foot of banded ore.
7. Four feet of coarse ore, mostly fluorite.
8. Barren.
9. Lenses of fluorite up to one foot wide in one foot of sandy limestone.
10. About three feet of coarse fluorite with many vugs and some limestone lenses in fine-grained limestone.

N. 30° E. for about 200 feet. The ore is a replacement of limestone just below the sandstone, but the mineralization is feeble and usually does not exceed six inches to a foot in width. The succession below the sandstone cap at the portal is one foot of shale, eight inches of fluorite, six inches of shale, and four inches of fluorite. Most of the ore is highly oxidized. Apparently the dense, fine-grained limestone was unfavorable to extensive replacement. No stoping has been done in these workings.

A poorly planned mill at the mine is now in disrepair. The equipment includes grizzly, jaw crusher, crushing rolls, jigs, classifier, and wilfly table. Water for its operation was pumped from a sink-hole lake one mile south.

Robinson Mine (abandoned)

(SW. ¼ sec. 4, T. 12 S., R. 9 E.)

The Robinson mine (Pls. I and VII) is on the southwest slope of Lead Hill about four miles northwest of Cave in Rock. It was opened by Mr. George W. Robinson. Several small open pits and small drifts develop a blanket deposit two to three feet thick in which the ores are replacements of certain beds of Fredonia limestone not far below the Rosiclare sandstone. One pit 20 by 15 feet and 30 feet deep exploits a 6-inch vein of fluorite striking N. 45° E. and dipping 80° to the northwest. A few other smaller veinlets of fluorite were noted, but the vein type of mineralization is subordinate to replacement.

Minerals of the ores are white to deep purple fluorite, smoky quartz, and a little galena and sphalerite. Calcite is present in some of the veins but was not observed in the banded replacements. A little fluorite of optical grade has been found. Small amounts of cerussite and smithsonite are products of weathering.

A mill near the mine is now partly dismantled but was equipped with crushing rolls, Hartz jigs, and a concentrating table. The water supply was obtained from a spring which in turn was fed apparently from a sink-hole lake.

C. M. Miller Mine (idle)

(West central part of sec. 4, T. 12 S., R. 9 E.)

The C. M. Miller mine (Pl. I) is situated on the west side of Lead Hill. It was last operated by Basic Mineral Company, Pittsburgh, Pennsylvania, with C. M. Belt of Cave in Rock as superintendent. Several small branching drifts and small pits develop a replacement deposit, similar in general type to the deposits at Spar Mountain, in Fredonia limestone not far below Rosiclare sandstone.

Within a zone about six feet thick occur two or three flat-lying replacement zones of fluorspar ore as much as 1½ feet thick and parallel to the bedding. These zones are mainly white and purple fluorite. They carry occasional vugs which are usually lined with purple fluorite in crystals as much as three inches across. In some vugs crystals of white quartz as much as one-half inch across appear to have formed contemporaneously with the fluorite, and in others it encrusts fluorite crystals and is clearly younger. Galena is of spotty distribution but may form masses three to four inches across. It appears to have formed at the same time as the fluorite. At many places the ore is banded, in alternate bands of pale to deep purple fluorite one-fourth to three-fourths of an inch thick and containing individual crystals one-fourth inch across and bands of much finer granular texture three-fourths of an inch to one inch thick. The finer bands are mainly fluorite with lesser amounts of quartz or of quartz and calcite.

The preservation of fossils and of stylolitic structures (Fig. 30) in the ores are evidence that the ore was formed by replacement. The fluorspar replacement zones are sharp but irregular in outline. There is usually no difficulty in putting the pencil point on the exact contact between ore and limestone.

A mill located about a quarter of a mile northwest of the mine could not be entered. It carried a jaw crusher crushing rolls, and jigs. The water supply was run-off collected in a small pond and was inadequate except in wet seasons.

RENFRO PROSPECT

(West central part of sec. 23, T. 11 S., R. 8 E.)

The Renfro prospect (Pl. I), seven miles north of Elizabethtown, is on the farm of W. J. B. Renfro. In 1926 it was developed by a small open pit and a shaft 22 feet deep. A cross-cut from the shaft extended N. 65° W. for 28 feet.

The notable feature of the prospect is that the fluorite occurs in banded form as a replacement of limestone. The banded fluorite has been found through a vertical range of at least ten feet but development was insufficient to show its lateral extent.

CHAPTER VII—MINING AND MILLING

GENERAL

The topic of the mining and milling of fluorspar has been well covered in a recent comprehensive technical discussion,[1] so that only the more essential features of the methods are here summarized.

MINING

Where vein and blanket deposits are near the surface they have been broken up by weathering so that they are incoherent and can be easily and cheaply excavated by shoveling or other simple methods. Weathered outcrops of veins are likely to be wider and richer than the underlying unweathered portions of the veins because the loose material tends to spread and "creep," especially on slopes, and because they represent the residue of large thicknesses of fluoritic material concentrated during the development of the present land surfaces. Fluorite is highly resistant to the action of air and water and therefore tends to remain while other components of the deposits are washed away or dissolved, so that the fluorite fragments therefore lie in a matrix of clay from which they can easily be washed free. In the early days of the development of the Illinois deposits most of the production was obtained by open-pit mining from deposits of this sort. Open-pit mining is no longer practiced in the Rosiclare district but during the summer months it is practiced in the blanket deposits at Spar Mountain. Pick and shovels often suffice for excavating, but vertical holes may be drilled by hand and the materials broken with light charges of dynamite so that the working face remains steep. Waste is trammed to the dump, and the crude fluorspar is loaded at the pit directly into one-ton trucks and hauled to the mill at Cave in Rock.

In underground mining at Spar Mountain during the winter months when open-pit mining is suspended, drifts are first run from the outcrop and from these drifts rooms are turned off usually at irregular intervals. Pillars 10 to 15 feet across, preferably in leaner materials, are left to support the roof. The working face becomes a single long irregular wall which is continually extended from the main drift. The method resembles the advancing longwall method of coal mining except that there is no back-filling. Stoping continues until the deposit thins to the minimum minable width of about two feet. Vertical timber props are used where the roof is weak. especially near the outcrop, but as a rule little timbering is necessary.

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[1] Ladoo, Raymond B., Fluorspar, its mining, milling, and utilization: U. S. Bureau of Mines Bull. 244, 1927.

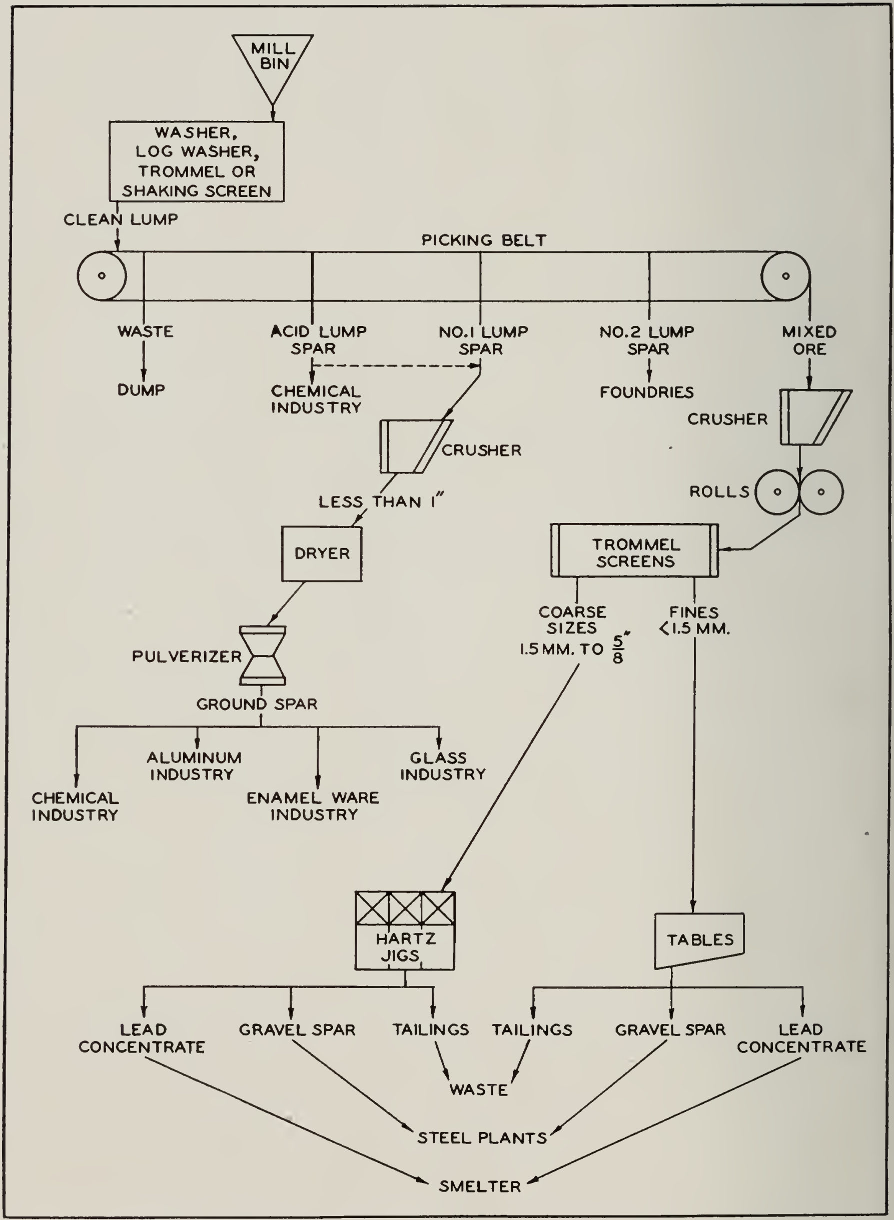
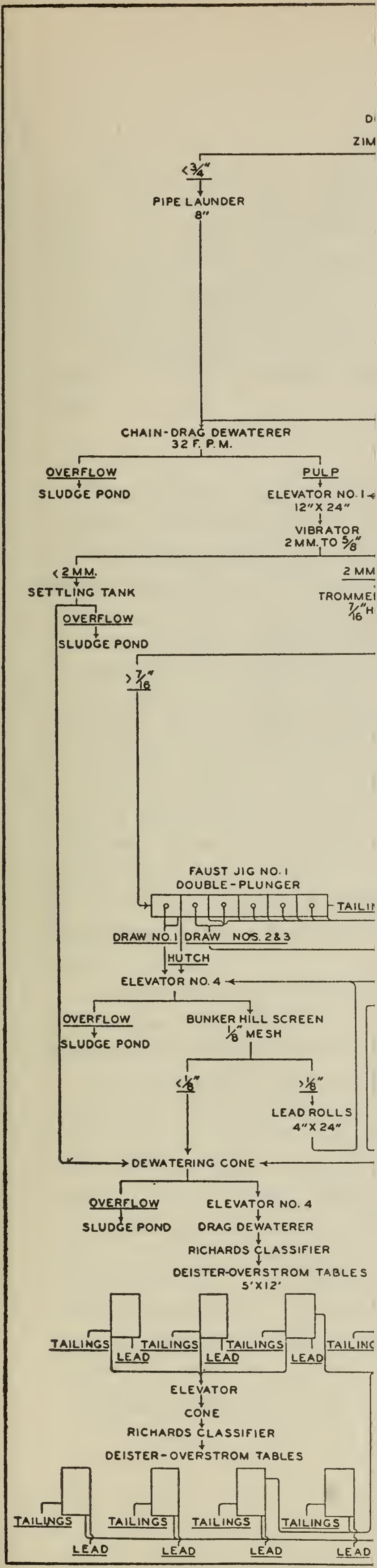


FIG. 47. Flow sheet of a simple fluorspar mill showing the essential processes.


D
ZIM
<3/4"
PIPE LAUNDER 8"
CHAIN-DRAG DEWATERER 32 F.P.M.
OVERFLOW
SLUDGE POND
PULP
ELEVATOR NO. 1 12"X24"
VIBRATOR 2 MM. TO 5/8"
<2 MM.
2 MM
SETTLING TANK
TROMME
7/16" H
OVERFLOW
SLUDGE POND
>7/16"
FAUST JIG NO. 1 DOUBLE-PLUNGER
TAILI
DRAW NO. 1
DRAW NOS. 2&3
HUTCH
ELEVATOR NO. 4
OVERFLOW
SLUDGE POND
BUNKER HILL SCREEN 1/8" MESH
<1/8"
>1/8"
LEAD ROLLS 4"X24"
DEWATERING CONE
OVERFLOW
SLUDGE POND
ELEVATOR NO. 4
DRAG DEWATERER
RICHARDS CLASSIFIER
DEISTER-OVERSTROM TABLES 5'X12'
TAILINGS
LEAD
TAILINGS
LEAD
TAILINGS
LEAD
TAILIN
ELEVATOR
CONE
RICHARDS CLASSIFIER
DEISTER-OVERSTROM TABLES
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Flow shee

Where the deposit is thick temporary tracks are laid from the main drift to the face; where thin the fluorspar is shoveled back to the drift by hand. It is loaded into one-ton steel cars and trammed by hand or by mules to the portal, where it is dumped into storage bins. Drilling is done by hand or by compressed air which is furnished by steam plant and air compressor located near the Hillside shaft (Pl. VII).

The underground methods of mining used in the vein deposits of fluorspar do not differ materially from those usually used in working metalliferous veins.

Milling

The details of the milling of fluorspar have been also comprehensively treated.[2] The separation of the fluorspar (specific gravity 3.0 to 3.25) from its prevailing valueless gangue of calcite (specific gravity 2.72) and the separation of both of these minerals from galena (specific gravity 7.4 to 7.6), which is a minor but valuable component of most of the deposits, constitute the main problem. The calcite occurs both as vein calcite and as limestone. The differences in specific gravity of calcite, fluorite, and galena are sufficient so that jigs and shaking tables provide a separation clean enough for most purposes. Careful hand-picking to exclude essentially all calcite is necessary in preparing spar for acid-making. Galena rarely constitutes more than 0.5 per cent by weight of the material milled. The galena concentrates carry seven to eight ounces of silver per ton. Quartz (specific gravity 2.65) may be present either as vein quartz or as sandstone, which constitutes the wall rock at some places. The sandstone is carefully eliminated in mining and the vein quartz is seldom sufficiently abundant to be a problem in milling. Barite is so localized that it can readily be separated in mining and is not a factor in milling.

A generalized flow-sheet shows the essential steps in the simplest type of fluorspar mill (Fig. 47). In contrast to this are the complicated flow-sheets of the Hillside and Rosiclare Mills (Pls. VIII and IX).

The milling of the ore from the blanket deposits mined by open-pit methods at Spar Mountain is simplified and cheapened by the scarcity of both calcite and galena so that jigs or concentrating tables are unnecessary. The finished product constitutes 85 to 90 per cent of the crude material. At the mill of the Benzon Fluorspar Company at Cave in Rock very muddy crude material is allowed to lie in open stock-piles to break up before it is milled. The mill consists of a jaw crusher which reduces all material to two inches or less. From this the fluorspar goes to a washing trommel screen with half inch holes. The oversize from the trommel goes to a picking belt, from which waste is picked out by hand and from which also the best spar is picked to yield "acid spar," the remainder going to the storage bin. The

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[2] Ladoo, Raymond B., Op. cit.

undersize from the trommel goes through a log-washer and then to the storage bin.

Sphalerite, or zinc sulfide (specific gravity 3.9 to 4.1) occurs in places in some of the veins of the Rosiclare district as a minor component. Its specific gravity is so near that of fluorspar that it cannot be cleanly separated from the latter by jig or table methods. Much sphalerite-rich material has been avoided in the mines or sent to the dumps but within recent years the Franklin Fluorspar Company employed flotation to re-treat zinc-rich fluorspar.

ANALYSIS

The accurate commercial analysis of fluorspar involves a complicated technique which has been recently set forth.[3]

In making the daily analysis of the mill product at the Benzon mill at Cave in Rock, a sample of the combined product of the picking belt and the log-washer is taken every 30 minutes. After quartering, the sample is pulverized on a bucking board so that it will pass a 200-mesh screen. Then the sample is first treated with a ten per cent solution of acetic acid and boiled on a hot plate for 40 to 50 minutes, which dissolves the calcium carbonate ($CaCO_3$). After washing and drying, the residue is weighed and the loss of weight represents calcium carbonate. About five cubic centimeters of hydrofluoric acid is added to the residue in a platinum crucible and the sample is heated to dryness. Another five cubic centimeters of hydrofluoric acid is added and the sample is again heated to dryness. Finally ten drops of concentrated nitric acid and five cubic centimeters of hydrofluoric are added and the sample is heated to a dull red heat. The loss of weight by this treatment represents silicon dioxide (SiO_2). The remainder is reckoned as calcium fluoride (CaF_2).

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[3] Lundell, G. E. R., and Hoffman, J. I., The Analysis of Fluorspar: U. S. Bureau of Standards, Research Paper No. 51, 1929.

CHAPTER VIII—MARKETING, USES, AND PRODUCTION OF FLUORSPAR

Fluorspar may be marketed in lump form, as crushed "gravel spar", or pulverized. Strictly speaking, "gravel spar" comprises two classes of material, of which one is produced by simple washing or screening of the soft, partly decomposed surface portions of the deposits and contains material up to an inch or even larger in size, and the finer is produced by crushing, jigging, and tabling of deeper, solid, unweathered portions of the deposits and will pass a one-fourth inch screen. The bulk of the fluorspar production is "gravel spar," which is utilized mainly in steel making.

The Illinois production of fluorspar from 1880 to 1929 is shown in figure 48, as are also the Kentucky production, the total for the United States, and imports and exports.

Fluorspar has many uses.[1] In 1927 the Illinois output of fluorspar was utilized as follows:[2]

Percentages of fluorspar used by different industries

	Per cent
Steel making	83
Foundries	3
Glass making	5
Enamel ware	4
Hydrofluoric acid	4.5
Miscellaneous	0.5
Total	100

The principal use of fluorspar is in the manufacture of steel in open-hearth furnaces. The hearths of most of these furnaces have a so-called "basic" lining of magnesite ($MgCO_3$) or dolomite ($[CaMg]CO_3$), and limestone or dolomite also forms part of the charge. Under these conditions much of the sulfur and most of the phosphorus in the pig-iron is removed with the slag. An average of about 8 pounds of fluorspar per ton of steel is used in this process to make the slag more fluid at furnace temperatures and thus to facilitate its combination with sulfur and phosphorus. The so-called "gravel" spar is commonly used in steel making, as steel manufacturers object to fines. Jig practice fixes the lower size limit at about one-sixteenth inch. Table concentrates are finer (2 millimeters and less in size) and are mixed with the jig product, to be marketed as gravel. Sulfides in the fluorite are undesirable in steel making because they are a source of sulfur. All

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[1] Ladoo, Raymond B., Op. cit., pp. 57-75.

[2] See Mineral Resources of the United States, 1927, Pt. II, Fluorspar and Cryolite.

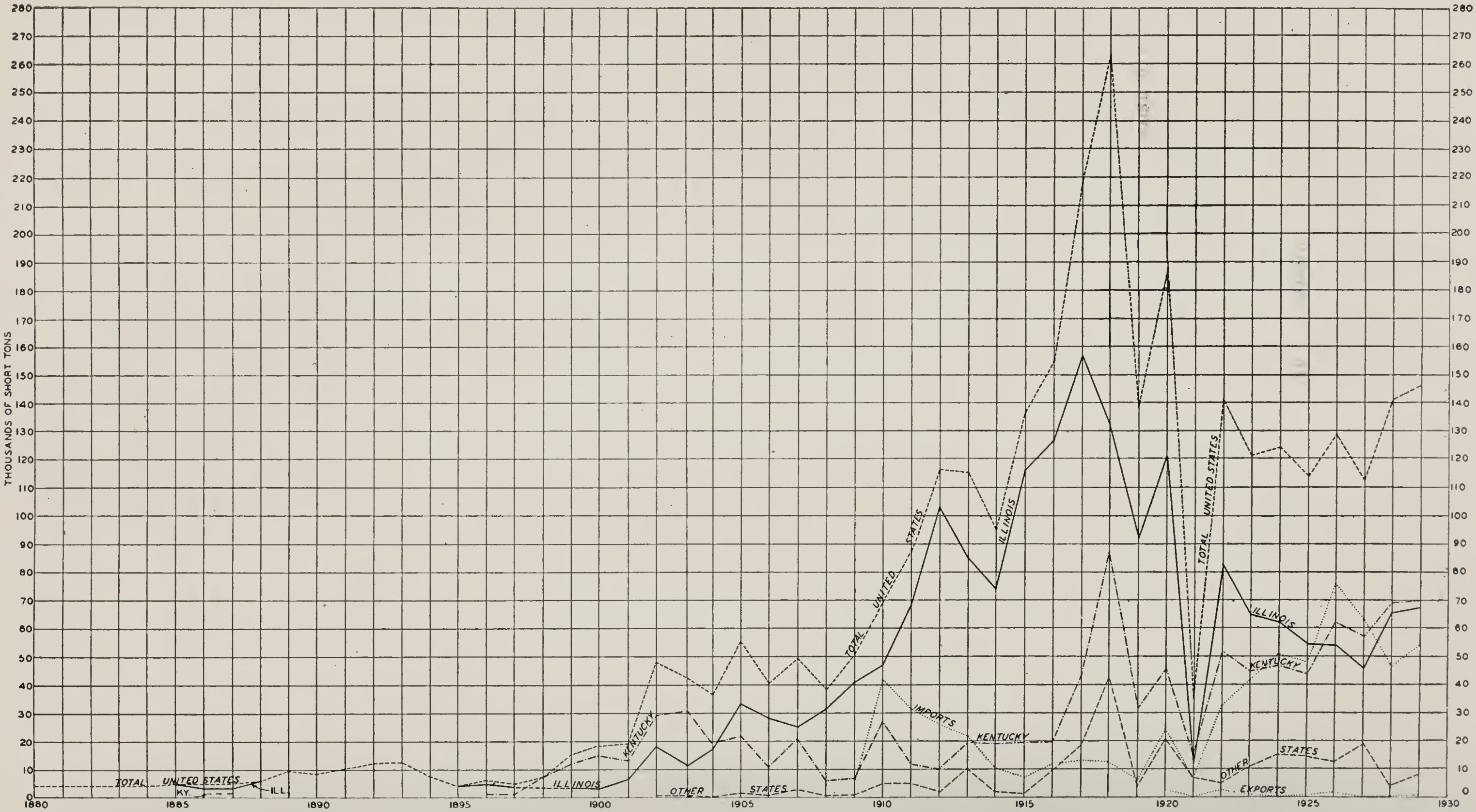

FIG. 48. Graph showing sales of fluorspar in the United States, and imports and exports, 1880 to 1929. (United States Bureau of Mines, Mineral Resources of the United States, published annually.)

except zinc sulfide—sphalerite—are readily removed by gravity methods. Sphalerite may be removed by flotation, but this process requires fine grinding and produces fluorite too fine for steel making but not pure enough for the uses to which pulverized fluorite is applied. Fluorspar for steel making is generally sold on the basis of at least 85 per cent CaF_2, less than 5 per cent SiO_2, and less than 0.3 per cent sulfur. About 80 per cent of all of the fluorspar consumed in the United States is used in the open-hearth steel furnaces.

Fluorspar is also used as a flux in the cupola furnaces of many foundries. For this purpose the lump form is preferred, and some foundries will accept lumps up to 12 inches across. Minor amounts of fluorspar are used as a flux in many other metallurgical operations.

The second important use of fluorspar is in the manufacture of hydrofluoric acid and its derivatives, which industry absorbs about 8 to 10 per cent of the fluorspar used. For this purpose a high degree of purity is essential and specifications usually require at least 97 per cent calcium fluoride (CaF_2), less than two per cent silicon dioxide (SiO_2), and less than one per cent calcium carbonate ($CaCO_3$). Much hydrofluoric acid is made by the aluminum industry for use in the manufacture of sodium aluminum fluoride or artificial cryolite, which is a component of the electrolitic bath in the manufacture of aluminum.

Small amounts of fluorspar are used in the manufacture of white opaque glass and of opalescent glass, for which a high grade spar of about 95 per cent CaF_2 is usually demanded. The iron content, expressed as Fe_2O_3, must be less than 0.1 per cent. Some fluorspar is used in the white and colored enamels used in coating kitchenware, et cetera.

The interior portions of some crystals of fluorspar in some of the Illinois mines are clear, colorless or nearly so, and transparent. Even if small, such clear portions are utilized in the manufacture of particularly fine quality lenses for microscopes and other optical instruments.[3]

The variety of commercial grades of fluorspar marketed by the Franklin Fluorspar Company, is shown below.

1. *Franklin Special.* Pure lumps, hand-picked, grinding pure white.

Specifications:

At least 97.5 per cent CaF_2
Less than 1.0 per cent SiO_2
Less than 0.1 per cent Fe_2O_3
Free from lead and zinc

Used for pottery manufacture and enameling. Shipped ground and in bags to prevent contamination in transit. Seventy per cent passes a 200-mesh screen and 93 per cent passes a 100-mesh screen.

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[3] Pogue, Joseph E., Optical fluorite in southern Illinois: Illinois State Geol. Survey Bull. 38, 1919.

2. *Acid Spar.* Hand-picked.

Specifications:

At least 98.0 per cent CaF_2
Less than 1.0 per cent SiO_2

Used mainly in the manufacture of hydrofluoric acid, hence color and iron content is less important than in Franklin Special. Furnished in lump form or ground.

3. *No. 1 Standard.*

Specifications:

At least 95 per cent CaF_2
Less than 3 per cent SiO_2
Less than 0.1 per cent Fe
Only traces of lead, zinc, and sulfur

Used by most glass and enamel manufacturers. Furnished in lump form or ground.

4. *No. 1 Special.*

Specifications:

Same as No. 1 except that maximum iron content is 0.25 per cent

Used by manufacturers of vitreous or glass ware where slightly higher iron content is permissible.

5. *No. 2 Lump*

Specifications:

At least 85 per cent CaF_2
Less than 5 per cent SiO_2
2½ points of CaF_2 may compensate for each point of excess silica
Fines not over 3 per cent

Used as flux in foundries.

6. *Washed Gravel—85 and 5.*

Specifications:

At least 85 per cent CaF_2
Less than 5 per cent SiO_2

Used as flux in basic open-hearth steel furnaces, foundry practice, et cetera. Crushed to pass a one-inch screen.

The markets for Illinois and Kentucky fluorspar lie mainly in the Mississippi Valley and Great Lakes region. In Pittsburgh, Wheeling, and other eastern points the markets are divided with foreign spar. In Buffalo and points farther east foreign fluorspar dominates the markets.

The fluorite production of the western states is mainly consumed in the west.

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Plate III